AN ILLUSTRATED GUIDE TO THE SLIT-LAMP

OXFORD MEDICAL PUBLICATIONS

AN ILLUSTRATED GUIDE TO THE SLIT-LAMP

BY

T. HARRISON BUTLER, M.A., D.M. (OXON.)
M.R.C.S. (ENG.), L.R.C.P. (LOND.)

LATE RADCLIFFE TRAVELLING FELLOW OF THE UNIVERSITY OF OXFORD
SURGEON TO THE BIRMINGHAM EYE HOSPITAL
HONORARY OPHTHALMIC SURGEON TO THE COVENTRY AND WARWICKSHIRE HOSPITAL
AND TO THE WARNEFORD HOSPITAL, LEAMINGTON

HUMPHREY MILFORD
OXFORD UNIVERSITY PRESS
London Edinburgh Glasgow Copenhagen
New York Toronto Melbourne Cape Town
Bombay Calcutta Madras Shanghai

First printed 1927

Printed in Great Britain by
Hazell, Watson & Viney, Ld., London and Aylesbury.

PREFACE

THIS work is founded upon Lectures given at the Oxford University Slit-lamp Courses in 1924 and 1925, the Doyne Memorial Lecture of 1924 and the Montgomery Lectures, delivered at Trinity College Dublin, in April 1926. They have been completely revised with the addition of new material, and have been recast in book form. The volume makes no claim to be an exhaustive Text Book, but must be regarded as an elementary introduction to the technique of the slit-lamp, and a summary of the discoveries that have been made with it during the past decade.

All my work has been done with the Zeiss slit-lamp, and I have no experience of other models. I feel, however, that this instrument, which has, during the last ten years, been created step by step by Gullstrand, by Henker, and by Vogt and his co-workers, represents a combination of theory and practice which cannot in the nature of things be found in any of its rivals.

The reader will meet the name of Vogt in every chapter; many of the quotations of his views are taken, not from his published work, but from the Lectures and personal instruction which he gave during the slit-lamp courses at Zürich in 1923 and 1924. Almost the whole of our technique and the majority of the discoveries made with the slit-lamp we owe to Vogt, who has created what amounts to a new science. I cannot too strongly advise beginners in slit-lamp work to study his Atlas,[1] and to read his published work.

The drawings which illustrate this book are for the most part memory pictures drawn from rough sketches made in the out-patient departments, but some have been carefully drawn from the actual patient. The illustrations have been chosen with the idea of presenting the appearances seen in ordinary clinical work. Many abnormalities are not included, because I have not so far seen them, or have been unable to find time to draw them.

My thanks are due in the first place to Professor Vogt for the immense pains he took to instruct me in the technique of the in-

[1] This Atlas is unfortunately out of print.

strument, and for allowing me to act as one of his demonstrators in the Course held at Zürich in 1924. I am indebted to Mr. Basil Graves and to Miss Ida C. Mann for much help and for valuable suggestions.

I wish to thank the Council of the Ophthalmological Society, the *British Journal of Ophthalmology*, the *Archives of Ophthalmology*, the *British Medical Journal*, the *Lancet*, and *Brain*, for permission to reproduce drawings which have already appeared in their publications, and for the loan of the blocks. I express my gratitude to the Medical Faculty of the University of Birmingham for awarding me the Marshall Prize to help to defray the cost of illustrating this book. Finally, I must record the debt that I owe to my wife for her sympathetic co-operation, especially in the arrangement of the illustrations.

I strongly advise my readers to study Koby's book on the slit-lamp, translated by Goulden and Harris. Many features of the work are there expounded which I have merely mentioned, others lightly touched upon by Koby have been elaborated in this book. The two works are not in any sense rivals, but can be considered as supplementary to each other.

T. HARRISON BUTLER.

2, STIRLING COURT,
EDGBASTON,
BIRMINGHAM.
January, 1927

CONTENTS

LIST OF ILLUSTRATIONS

LIST OF COLOUR PLATES

AN ILLUSTRATED GUIDE TO THE SLIT-LAMP

CHAPTER I

THE APPARATUS

THE corneal microscope has been in use for about twenty-five years. Originally invented by Czapski, it has been modified by Zeiss, and in its present form is an adaptation of the well-known Zeiss dissecting microscope. At first the instrument was used with an inadequate illumination, and it was not till Henker combined it with Gullstrand's slit-lamp that it attained its full measure of usefulness.

On the top of each microscope there is a large screw and under it a hole.[1] This is for the attachment of the quadrant that held the original electric lamp, a source of light that afforded only a diffuse illumination, and limited the range of observation to the cornea and iris. The slit-lamp has greatly increased the efficiency of the microscope, both by raising the intensity of the light, and by giving us the ability to direct the beam of light upon any desired spot. Much that we see with the microscope can be made out with a simple loupe and even with the naked eye. The essential advance conferred by the apparatus is due not so much to magnification as to the improved illumination, to the combination of the microscope with the slit-lamp.

The corneal microscope gives full stereoscopic vision. The Porro prisms erect the image and allow the eyepieces to be adapted to the inter-pupillary distance of the observer. To obtain this stereoscopic effect and to avoid asthenopia great care must be taken that the inter-pupillary distance is correctly adjusted. We hold the microscope by the drums and open and shut them till the image is seen stereoscopically and vision is comfortable. When the object has been focused we again adjust the distance between the oculars.

The microscope rotates upon a vertical spindle which is provided

[1] This is not present in the later models.

with a brake. When working with the glass-topped table it is not necessary to have the spindle loose, but with the mechanical slides we must occasionally loosen the brake to allow the instrument to be swivelled. A tilting device is fitted. In general we work with the tubes horizontal, but we tilt the microscope to observe the lower aspect of the eye, and for children, because the instrument will not lower sufficiently for their small heads.

On the left focusing screw there is a graduated slip-ring, Ulbrich's drum. This is divided into tenths of a millimetre and records the travel of the microscope upon its slide. If this be adjusted to zero it does not move when the microscope is focused backwards, but as soon as we focus forwards the ring travels and records the distance. We shall describe its use later.

The microscope can be obtained with a round foot with three steel knobs to slide upon a smooth glass-topped table, or it can be fitted with a mechanical stage, a double slide. The latter form is heavier and more robust, and is to be recommended for hospitals where the instrument is used by all and sundry and may have to endure some rough usage. For private work, and in hospitals where the slit-lamp is used by the surgeon alone, the glass-top table is greatly to be preferred. We find that unless the slides are carefully adjusted and well oiled, so that the microscope can be moved freely by hand without using the screws, the slides are disadvantageous in that the microscope cannot be instantly moved by one hand. With the glass-top model we hold the microscope by the screw which raises and lowers it, and can with one and the same motion adjust the instrument to any position and follow the movement of a roving eye. It can also be slued to one side rapidly, as may be desired. With the lower powers all the focusing can be done by sliding without using the screw. This is a great advantage, especially with a restless patient.

The three knobs must be screwed down till they are free from the leather washers. The glass top must be kept in first-class order. It should be occasionally dusted with talc powder and well rubbed with a chamois leather till it attains a high polish. The surface should be uniform, for if the glass is smoother in one place than another the microscope will slue when pushed about. The whole instrument should be well covered with some light material large enough to include the table, to prevent dust from settling upon the glass.

Objectives.—The most useful are A 0, A 2, and A 3. These with ocular 2 give magnifications of 15, 20, and 30. The lowest objective F 55 with a magnification of 9 is rather a toy, and its work can be done with the hand loupe. It is occasionally valuable for extracting foreign bodies from the cornea. The A 0 is a delightful and very useful objective and we highly recommend it ; it gives a large field of view and has sufficient magnification to show most of the details necessary in ordinary clinical work. A 0 is the beginner's objective and is ideal for teaching students.

A 3 is necessary for a detailed examination of the endothelial cells, and other minutiæ in the cornea, and for the study of deposits upon the posterior surface of the cornea.

Some of the later models of corneal microscope are fitted with an objective holder which carries all three lenses. This is not to be recommended, because the disc gets in the way of the naked-eye observation of the subject which is often of the greatest importance, and makes it difficult to aim the instrument. The objectives, unlike those of an ordinary microscope, are not often changed. Most of the work is done with A 2, and A 3 is only occasionally used. It is quite possible to manage with A 2 alone, but it is better to buy the full set at once, for if other objectives are added later, the whole microscope must be sent to the agents for adjustment. In changing the objectives the paired lenses must be held by the base, for the tubes that carry them are fitted to the base with delicate screws, and are easily displaced. Any alteration in position will lead to annoying asthenopia and to a disturbance of binocular vision. In later models the objectives are more robust and have an improved fitting for adjustment. It is unnecessary to say that when an objective is removed from the microscope it should never be laid down but invariably replaced in its own slide in the microscope box.

Oculars.—Those most useful are No. 2, No. 4, and a No. 2 with a micrometer scale. Personally we use No. 2 alone and find that there is little practical advantage to be gained by eyepiece magnification. Koeppe has recently pointed out that *the resolving power of a microscope depends not upon magnification but upon the numerical aperture of the objective.* A higher-powered objective costs more than an eyepiece, but it is well worth the extra expenditure.

The slides and screws of the microscope should occasionally be lightly oiled with sewing-machine or typewriter oil.

The linear magnifications given are those of the most recent lenses. The older objectives gave the following:

F 55 = 9 A 0 = 16 A 2 = 24 A 3 = 35

The latest No. 4 ocular exactly doubles the magnification given by No. 2. We have made no mention of the more powerful eyepieces, because they have no clinical value.

The Slit-lamp

The original slit-lamp was first demonstrated by Alvar Gullstrand in 1911. In its original form it was lighted by means of a Nernst lamp whose glowing homogeneous filament was focused upon the slit, which was not adjustable. The beam was concentrated upon the eye by an ordinary condensing lens held in the hand, and observations were made with a Zeiss field-glass. The arm which now carries the illuminating lens was added later.

After the war it became difficult to obtain the Nernst lamp, and the Nitra lamp now used was devised to take its place. The source of light is a thick helical filament. This heavy gauge is necessary to obtain a brilliant light, and postulates a low voltage. We can obtain the required voltage by stepping-down the town current, either with a resistance or, in the case of an alternating current, by a transformer, but even here a resistance is preferable, for it enables the voltage to be varied. The sole disadvantage, if indeed it be such, is that the resistance hums when used with an alternating current. The normal voltage of the lamp is 8 with an amperage of 6, but it is often useful to have a brighter light at command, and this can be obtained by pushing the lamp to 10 volts. The Nitra lamp is very robust—we have used one for over two years unchanged—and it will stand over-running for considerable periods; in fact we prefer to use 9 volts as the standard. With a variable resistance the voltage can be altered at will by sliding the contact. The voltage can be measured by attaching the poles of a voltmeter to the terminals of the resistance while the lamp is in circuit—that is, placing the voltmeter in a shunt. The instrument must not be included in the actual lamp circuit, for the lamp will cease to glow, and the voltmeter will register the town voltage and may be burnt out.

When the Nitra lamp was employed with the original Gullstrand

optical setting disadvantages at once arose, in that the spiral filament did not furnish a homogeneous light. Several attempts were made to overcome this fault, and eventually Vogt solved the difficulty by bringing the lamp closer to the lens system and so throwing the image of the filament on to the illuminating lens. This arrangement not only furnished a homogeneous light, but incidentally made it much brighter. The intrinsic brilliance of the Nitra lamp is considerably higher than that of the Nernst, and with the new optical arrangement the beam is about three times brighter than that of the old apparatus. The source of light is not, as some have stated, the brilliantly illuminated slit, but the homogeneously lighted opening of the collector-lens system.

A diagram of the paths of light in the old and new systems will be found in the *Zeitschrift für Augenheilkunde*, vol. xlvi, no. 6, p. 335. Schnyder here describes the optical arrangements and also gives a drawing of the compound collector system.

The Nitra lamp screws into a casing provided with a spring-balanced ring upon which two centring screws act. The casing fits into the lamp casting, and can be locked by a screw. The whole collector-lens system can be moved laterally by a screw which forms the fine adjustment for centring. To adjust the filament centrally we first see that the fine-adjusting screw is in mid-travel. We now loosen the set-screw and also place the illuminating lens at the end of the long arm in mid-travel. We hold a visiting-card in front of the illuminating lens and twist the lamp housing till the filament is vertical, and then draw it backwards and forwards till the image of the filament is sharply focused upon the card. The filament is centred by turning the screws that move the spring-balanced collar. The image must be raised or lowered till an equal amount shows on the back of the diaphragm tube. Finally the last adjustment is made by the screw which moves the lenses. Before using the slit-lamp always note that the filament is correctly focused and centred. As it warms it may move to one side and must be replaced by a slight turn of the fine-adjustment screw. Some lamps give a double image of the filament. This is due to irregularity in the glass of the bulb. Such a bulb must be returned to the maker. If the owner of the lamp has not been able to attend a course where he will have been taught how to adjust the instrument, he should ask the makers, or a friend who understands the correct procedure,

to demonstrate to him how to centre the filament. It is impossible to obtain good results from a slit-lamp which is in faulty adjustment.

The collector-lens system is placed in front of the lamp and anterior to this the adjustable slit. This was invented by Vogt, who thereby gave us the most important feature in the modern slit-lamp, the "*optical section*." The width of the slit is governed by a screw on the top of the casing which narrows the opening till it is reduced to one-fortieth of a millimetre. With such a narrow slit the amount of light that passes is small, and to obtain the requisite illumination an arc-lamp is necessary.

In practice the slit is never narrowed to its smallest dimension. The micro-arc-lamp is not necessary for routine clinical work, but is called for in certain branches of research. It is necessary for examining the vitreous and the retina under high powers. There may be some danger from using the arc-lamp upon the human eye. The eyes of rabbits have been exposed to the full arc for long periods without damage, but it by no means follows that the human eye is equally tolerant, and it is possible that the lens might be damaged. For this reason when using the micro-arc-lamp the slit must be used fully contracted and the eye must be examined only for a limited period.

It is usual to fit Koeppe's diaphragm tube in front of the slit-lamp between it and the illuminating lens. It should be placed about three inches from the slit. This adjunct is not necessary, but it is convenient in that it keeps the light off the patient's face and makes for better dark-adaptation in the observer. In front of the tube there is a cell into which we can slip a yellow-tinted glass or a red-free filter. Koeppe's disc containing a series of tinted glasses is not advised; we have one and never use it. A yellow-tinted glass is used to examine the conjunctiva and a light-coloured iris. It mitigates the dazzle and allows detail to be seen.

At the end of the light-arm there is a rack-and-pinion fitment carrying a lens. There is some confusion regarding the name of this lens, but we shall use the German term "*illuminating lens*." The lens is now fitted with the *Aruga screw* which raises and lowers it, and allows us to displace the beam without altering the position of the lamp-arm. This is an essential addition and should be obtained.

The original illuminating lens was two and a half inches in dia-

meter, and had a focal length of seven centimetres. It was not completely achromatic, and its large size prevented the close approximation of the lamp-arm to the microscope. Vogt cut the edges off and presented his aspherical lens. This was an improvement, but the lens was still not achromatic. Vogt finally devised the small lens that is now almost universally employed for clinical work. His lens is now achromatic, and has a focal length of ten centimetres. The long-focus lens is a little more difficult to focus than the shorter, but it is more practical in that it has a longer useful portion than the lens with shorter focus, and so gives a deeper optical section. The difference between the two will be appreciated if the beams be passed through a glass trough containing fluorescein, or through a cloud of cigarette smoke.

The essential differences between the two lenses and between the old Gullstrand adjustment of the lamp and Vogt's modern method are carefully described in Koby's book on the slit-lamp.

The illuminating lens must be kept clean, and in cleaning it avoid leaving off with vertical strokes; a circular or horizontal movement is better. Vertical streaks alter the character of the beam, and may lead to mistakes in estimating the "flare" in the aqueous. This source of error has been pointed out by Graves.

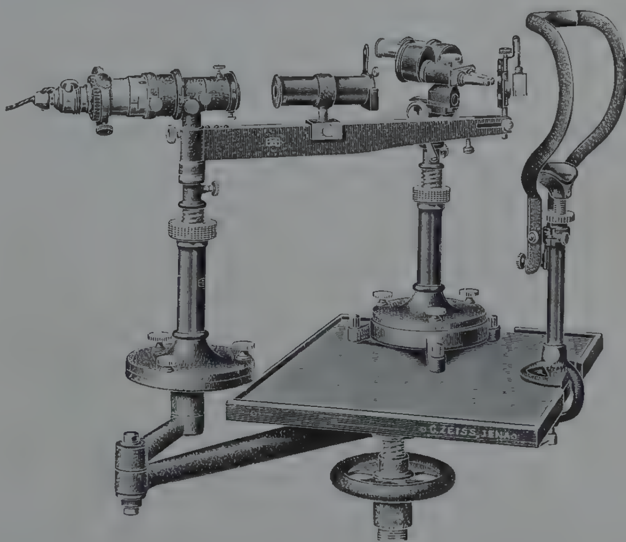


Fig. 1.—The Gullstrand slit-lamp and Czapski corneal microscope.

The Combined Apparatus

The association of the slit-lamp with the microscope and the mechanical arrangements for carrying the lamp on a double arm we owe to Henker. The general appearance of the apparatus and of the microscope are shown in Figs. 1 and 2.

The resistance should be attached to the wall and backed with asbestos, as it gets very hot. The wires to the lamp should be led

to a ring in the ceiling and then drop to the microscope in such wise that they are not in the way of the observer. There should be an adapter in the wire to enable it to be detached so that the whole instrument may be covered by a cloth.

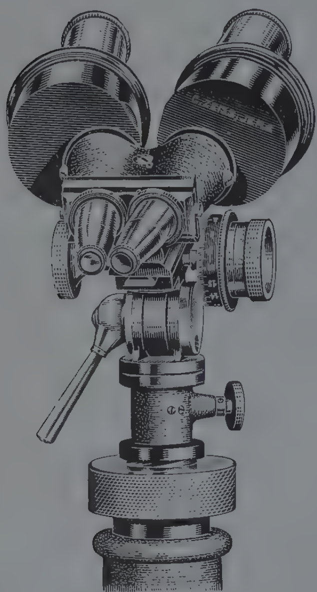


FIG. 2.—The Corneal Microscope, showing Ulbrich's graduated drum.

It is convenient to have adjustable stools for the patient and observer, so that both may be comfortably seated. The whole table raises and falls, being governed by a large screw wheel which should be kept well lubricated. There is a lock-screw to fix the table, but it is never used.

The head- and chin-rest are adjustable. Practically the head-rest is rarely altered, the necessary adaptation being made by the chin-rest. This should be covered by a square of thin paper; we cut a paper table-napkin into four, and use a fresh piece for each patient. This is very necessary, for a patient may breathe into the chin-rest and leave it full of water.

The patient sits in a comfortable position and rests his hands on the table. He should be asked to look in the desired direction, and a glow lamp may be provided to aid fixation. A roving patient should not be worried to fix any object. It is far better to follow his eye with the lamp and microscope, a faculty that comes with practice.

The moment the examination is completed the light must be moved away from the eye, and should be switched off if any long pause is made in the observation. Some patients have a definite time-limit, and if this be exceeded the eye begins to water and the examination must be interrupted. The narrow beam does not cause the slightest inconvenience, in fact it is hardly perceived.

In general the eye is examined with an undilated pupil, but for some purposes mydriasis is necessary.

CHAPTER II

METHODS OF ILLUMINATION

THE beginner must learn to focus the light and the microscope rapidly and automatically upon the same object, and attain the faculty of transferring the combined focus from one object to another with certainty and ease. Practice should begin upon freshly enucleated pig's eyes. A suitable holder can be fashioned with the aid of a strong pair of scissors and pliers from a bit of a condensed-milk tin. The shape of the pig's-eye holder is shown in Fig. 3. It is hooked on to the forehead rest and the light and microscope adjusted upon it. We roughly aim the microscope upon the object by sighting along it with the eye before we look through the oculars. At first it is not quite a simple matter to find the eye with the microscope.

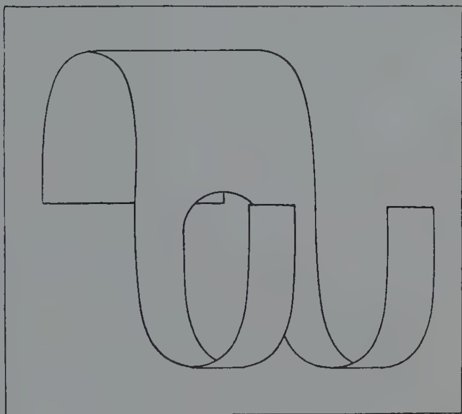


FIG. 3.—The tin frame for holding a pig's eye.

The original corneal microscope was associated with one type of illumination, the *diffuse*. The slit-lamp furnishes several. It is essential to master the right use of these varieties, and to learn to apply the best form instinctively. Constant practice is necessary to attain perfection in illumination.

Diffuse Illumination.—This method is valuable in the examination of the iris. We place the slit-lamp at an obtuse angle to the microscope and throw the beam slightly out of focus across the surface of the iris, and so get a diffuse illumination over a wide area. We may also employ diffuse lighting to reveal a large surface of the anterior capsule and to study a posterior capsular cataract. We use the full width of the slit for these investigations. A good diffuse light may be obtained by placing Graves' cylindrical lens

behind the illuminating lens, and throwing the beam out of focus.

Direct Focal Illumination.—This is the most generally useful variety of lighting, and it may be obtained from the broad beam, from the narrow beam, or from the pencil-beam which is obtained by using one of the pin-point apertures that are to be found in the disc in front of the slit. We can shorten the beam by turning the stenopaic slit that is found in the same disc somewhat obliquely. In focal illumination the beam is accurately focused upon the object under observation, whether it be in the cornea, the anterior chamber, the lens, or the vitreous.

Retro-Illumination, the "diaphanie" of the French, or *trans-illumination.*—This is one of the most valuable assets of the slit-lamp. We focus the light upon a suitable mirror, and use this reflection as the source of light. It may be furnished by the broad or narrow beam, or by the pencil- or dot-beam. We may use the iris, the lens, or the posterior capsule as mirrors. To examine the cornea by transmitted light we usually choose the iris as the mirror, and to obtain the best effect the pupil should be undilated. A light iris, especially a yellow, gives better illumination than a brown iris.

The iris is retro-illuminated from the lens and the posterior capsule.

Retro-illumination of the cornea from the posterior lens capsule has been studied by Graves. In some cases it reveals fine changes in the region of Descemet's membrane, not easily seen by other methods. The pencil, not the beam, is carefully focused upon the posterior capsule till the posterior lens shagreen is quite sharp, and then the microscope is racked back till the cornea is in accurate focus. It is generally necessary to dilate the pupil to get the best value from this variant of retro-illumination.

When using retro-illumination it is essential not merely to throw the light upon the chosen mirror, it must be accurately focused upon it. Thus, when using the iris, the light must be focused till the illuminated spot is as bright as possible.

Retro-illumination from the fundus has not received much attention. If we throw the beam upon the limbal region the light will sometimes penetrate the sclera and reach the retina. It is reflected back, and holes in the retinal layer of the iris will shine with red fundus-light. This is also occasionally seen when light is thrown through the pupil at an obtuse angle.

Indirect Lateral Illumination.—In some instances the iris reflects light so strongly that all detail is lost in the general dazzle; but by throwing the beam to one side of the part of the iris under observation, light is diffused laterally and every feature becomes clear. This method is used to examine the sphincter.

Sclerotic Scatter.—This term has been suggested by Graves for another variety of illumination. If the beam of light be directed upon the limbus the whole circumcorneal region lights up, and the glow is brightest opposite to the point of impact. The same phenomenon in a lesser degree is seen when the light is directed across the cornea on to the further limbal region. The light is reflected backward and forward between the two internal limiting surfaces of the cornea, and is scattered centrifugally all round the cornea. If it is thrown across the cornea it is first reflected back by the opaque sclera, and naturally in this case the pericorneal halo is not so bright. The halo is shown in Fig. 4. This drawing also illustrates the effect of fundal light showing up tears in the posterior layers of the iris. The radial tears were due to a blow upon the eye which made the pupil oval. Probably the alteration in shape is directly due to the laceration of the iris. They were present on both sides of the pupil.

FIG. 4.—Shows sclerotic scatter, and retro-illumination of the iris. In the first case the light is focused upon the limbus on the right side and the halo is seen all round the cornea. The radial tears in the posterior layer of the iris are seen lighted up when the beam is directed from the right side into the lens.

Whereas the light traverses the cornea which is not optically

homogeneous it is obvious that this structure must become internally illuminated, *relucent*, to use another apt word we owe to Graves. This internal glow shows up tenuous corneal opacities which are difficult to make out by other methods. Sclerotic scatter is a form of illumination suitable only for low magnifications.

Illumination in Mirror Light, Specular Illumination.—This interesting variety we owe to Vogt. Generally, in examining the eye with ophthalmoscope or loupe, we try to avoid the bright reflex, but in mirror illumination we deliberately seek out and work in the zone of specular reflection. The method will be better understood if we study a simple example. Take an ophthalmoscope case and hold it in such wise that the image of a bright light is reflected in its shining surface.

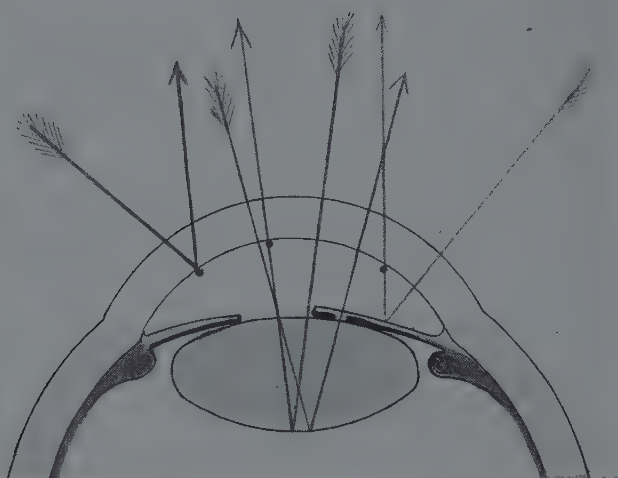


FIG. 5.—Shows direct focal illumination of an object upon the posterior surface of the cornea. Retro-illumination of a similar object by iris light. Retro-illumination of a hole in the posterior layer of the iris by light from the lens and posterior capsule. Retro-illumination of an object on the posterior corneal surface by light from the posterior lens capsule.

It will at once be noted that when we observe the area which mirrors the source of light we can see minutiæ in the shagreen of the leather that are invisible by ordinary illumination. To obtain mirror light we must direct our patient so to direct his gaze that his visual axis bisects the angle between the illuminating and the observing axes and lies in the same plane; in a word, he must look between the slit-lamp and the microscope. The exact direction will vary according to the portion of the cornea or capsule under observation.

Mirror light is chosen to examine the surfaces of the eye: the anterior and posterior surfaces of the cornea, the endothelial cells, the anterior and posterior lens, shagreen, and the epithelial cells of the capsule.

Oscillatory Illumination.—Koeppe describes this method in which

the lamp-arm is given an oscillatory motion. It is sometimes possible to see filaments and minute objects in an oscillating beam that are invisible when it is at rest. We have been able to see the fine threads which span the retro-lental space when we oscillated the light and quite unable to appreciate them with the beam at rest.

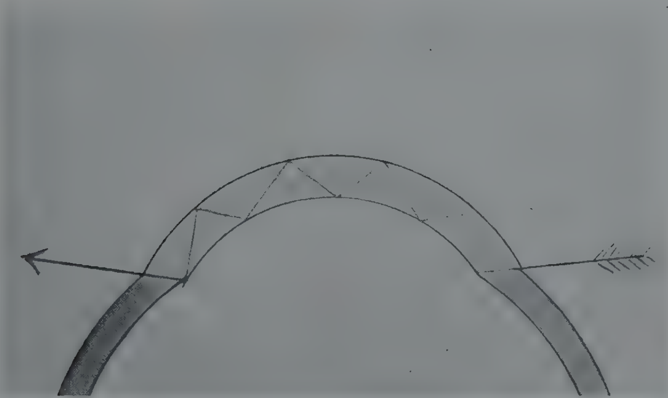


Fig. 6.—Illustrates sclerotic scatter. The beam enters the cornea at the limbus and undergoes double reflection between the internal limiting surfaces of the cornea.

Choice of Method. The relative value of these various ways of lighting the object, and the best to select, is purely a matter of experience and practice. The more we learn of the technique of illumination the more information the slit-lamp will furnish. There are some who underrate the value of the slit-lamp because they have never mastered the minutiæ of illumination.

The various methods are illustrated in Figs. 5, 6, 7.

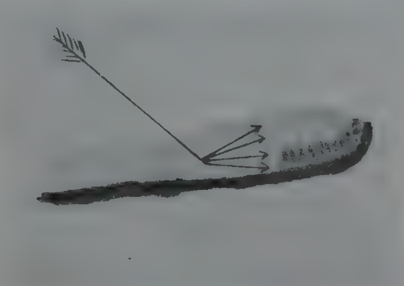


Fig. 7.—Shows indirect lateral illumination of the iris sphincter.

CHAPTER III

THE NORMAL CORNEA

THE *Corneal Prism.*—The cornea is not like a plate of glass, optically homogeneous, but is composed of a series of lamellæ which not only transmit light but also reflect and disperse it. In consequence when a beam of light traverses the cornea it produces a visible path of light, the cornea becomes relucent. The illuminated area of the cornea is a curved quadrilateral solid, a parallelepipedon. It seems most convenient to translate the German term for it, *prisma*, and call it the *prism*. Students seem to have some considerable difficulty in grasping the idea of the prism, but another homely illustration will make it clear. Let us take half the rind of a melon and regard it as the cornea, and the outer case of a common matchbox as the broad beam. Pass the matchbox through the rind and the part cut out will be a model of the corneal prism as seen with the broad beam. A similar prism is formed in the lens cortex of the adult, but it is not so sharp as the corneal prism, nor are its surfaces so nearly concentric. Considerable light is lost in the cornea and aqueous, and there is more dispersion in the lens.

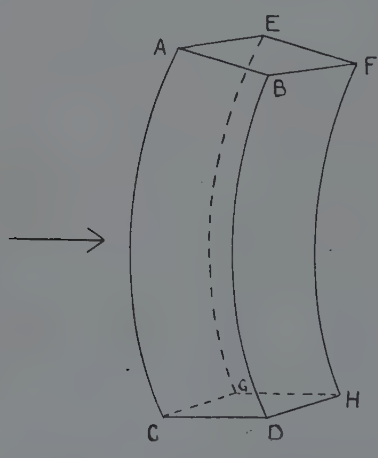


FIG. 8.—A diagram of the corneal prism. The light is coming from the left.

Fig. 8 is a diagram of the corneal prism. It has four sides and four edges. The light must be imagined as coming from the left. Adopting Vogt's lettering, the *epithelial surface* of the prism is *abcd*, the *endothelial* surface *efgh*. These two areas represent actual corneal surfaces. The last two sides of the prism mark out the limits of the beam of light, of the relucent area, and are not actual surfaces. We prefer to call them sections. *bfdh* is the *proximal section*, *aecg* the *distal section*. The distal section is

invisible and does not concern us. The important prism edges are *bd* and *fh*. *bd* separates the epithelial surface from the proximal section. *fh* is common to the proximal section and the endothelial surface. One of the first exercises with the slit-lamp is to learn to focus the line *bd* sharply, and this is followed by accurate focusing the line *fh*. Light, microscope, and intra-ocular distance must be adjusted till one of these lines is perfectly clearly defined. When this has been achieved the observer must learn to pass simultaneously from one to the other with both light and microscope, and practise till the adjustment become automatic.

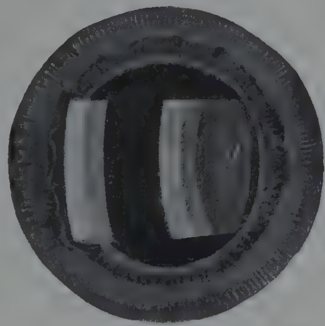


FIG. 9.—The appearance seen when the broad beam is thrown into the eye. The light comes from the left. On the left we see the corneal prism sharp and clear-cut. Centrally the less-distinct lens prism. Between the two is a dark space, the anterior chamber. The path of the beam through the anterior chamber can be faintly discerned in the drawing. To the right of the lens prism the architecture of the lens is displayed. All these structures are shown in sharp focus. In reality this is not the case.

The corneal prism alters in shape as the beam is narrowed. The section remains constant, but the epithelial and endothelial surfaces contract till they practically disappear, and instead of a prism we obtain a scymetar of light; this is a section of the cornea, the "*optical section*."

Fig. 9 shows the appearance seen when the broad beam is projected into an eye. To the left we see the corneal prism clearly defined. The epithelial surface is bright, the proximal section somewhat less illuminated. Behind the prism on the right is a dark space, the anterior chamber. Then we arrive at the lens prism, somewhat less clearly defined; and to the right we see the relucence of the lens. On the extreme right the feeble glow in the vitreous can be dimly perceived.

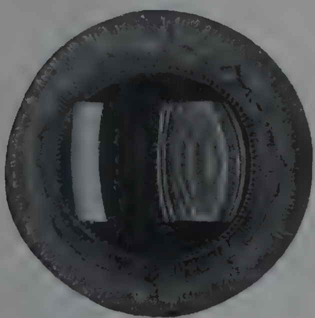


FIG. 10.—The same eye illuminated by the narrow beam, showing all the structures in profile, in optical section.

Fig. 10 shows the eye illuminated by the narrow beam. The corneal prism has now become a section, and to the right we see the profile of the lens.

The study of the prism can be facilitated by instilling fluorescein into the eye. The surface of the cornea is then covered by a thin film of tears coloured green, and the epithelial surface is sharply differentiated from the uncoloured

proximal section. This method is very useful for practice with the pig's eye.

Fig. 11 shows the corneal prism of a normal cornea magnified thirty times. We note that three of the edges are sharply defined; and two sides, the epithelial surface and the proximal section. The fourth edge, the line *eg*, is seen with some difficulty in the young cornea, but with practice in careful focusing of light and microscope it can be defined. This line is faintly indicated in the drawing. The distal section is invisible. In the senile cornea, and even more in late interstitial keratitis, the line *eg* is plain and the endothelial surface stands out clearly; in fact under these conditions it may reflect more light than the epithelial surface, which is now the more difficult to define. See Coloured Plate I, Fig. D.

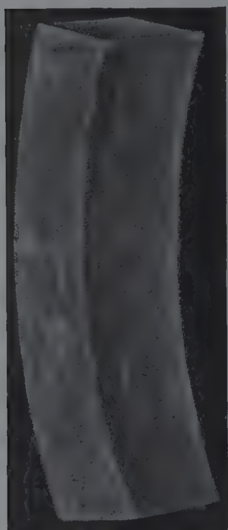


FIG. 11.—The normal corneal prism. The light is coming from the left. The mottled appearance of the parenchyma is shown and the corneal nerves. The side to the left is the epithelial surface, that to the right the proximal section. The line *eg* is faintly seen.

The substance of the corneal prism has a marbled appearance and is full of small nodules more opaque than the rest of the prism. Koeppe has seen in some of these the nodal points of an anastomosis of lymphatics, but his views have not obtained universal acceptance. The structures known as Bowman's tubes and Recklinghausen's canals are probably artifacts, and it is generally held that the slit-lamp has not confirmed their actual existence.

Corneal Nerves.—Crossing the prism are fine threads like cotton fibres. These are the corneal nerves. They are present only in the anterior two-thirds of the cornea and branch dichotomously. If they are traced back to the periphery of the cornea they are seen to thicken and become opaque. Here they have a medullary sheath which they lose in the transparent cornea. Under magnifications higher than those commonly employed in clinical work many interesting details can be made out. Occasionally at a branch there is a web, and nodes are visible along the course of the nerve. Details will be found in Koeppe's *Microscopy of the Living Eye*, and Gallemaert's *Microscopic Examination of the Affections of the Cornea with the Aid of the Slit-lamp*. Fig. 12 shows the corneal nerves leaving the limbus.

The *epithelial cells* are invisible with our apparatus. The beginner may think that he sees them, but he is being deceived by small bubbles upon the corneal surface. Although the actual cells are invisible the layers of cells can be seen as a thin, highly transparent film on the edge of the prism. The lamp should be overrun to 10 volts and then a fine focus brought upon the line *ac*. The prism will be seen to have a transparent halo of a definite thickness. This is the epithelial layer. This stratum can also be seen with the narrow beam, but we have found it easier to define with the broad beam.

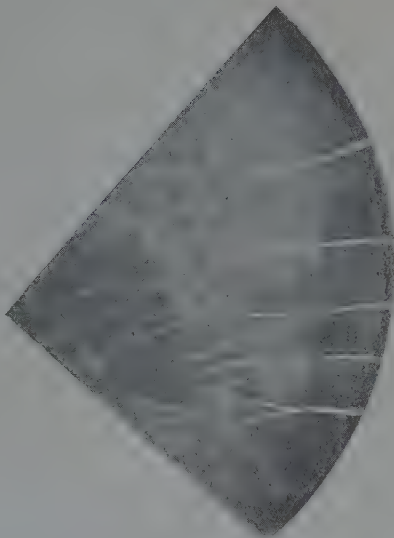


FIG. 12.—The corneal nerves emerging from the periphery and spreading over the cornea, branching dichotomously. We note that at the periphery they are thicker and opaque, because they still possess their medullary sheath.

Bowman's membrane in its normal condition is invisible, but when it is folded the edge of the fold is seen as a thin white line which may be mistaken for a nerve. An extreme case of radial folding is shown in Fig. 13. In this case of old central keratitis there were star-like figures superficial and deep in the cornea. One was due to folding of Bowman's membrane, and the deeper and coarser star to corrugations in Descemet's membrane.

FIG. 13.—Radial folds of Bowman's membrane seen as a fine star-like formation. Similar folds of Descemet's membrane take the form of a coarse star.

The endothelial cells can be seen in the zone of specular reflection. The study of these cells is important, perhaps more so than we yet realise, and the technique not quite easy to acquire. The beginner should commence with the pig's eye. Here the cells are larger than the human cells and their nuclei can be seen. The nuclei in the human cells are reputed to be invisible, but quite recently we were examining the eye of a miner and to our astonishment we noted that the endothelial cells were almost as large as those in the pig, and that the nuclei were obvious. The cells are hexagonal and have a yellowish colour. Among them are dark crater-like areas giving the impression

that we are observing the mountains in the moon. Vogt thinks that these "*craters*" are identical with those swellings on Descemet's membrane which project inwards and are known as the Hassal-Henle warts. I hardly think that this can be the case for all of them, because under certain inflammatory conditions of the cornea, such as disciform keratitis, all the endothelial cells in the region affected disappear and we see nothing but craters. As the cornea returns to normal the cells reappear and the craters are reduced to their normal number. In the healthy cornea the craters are more numerous at the periphery and they are conspicuous in the senile period.

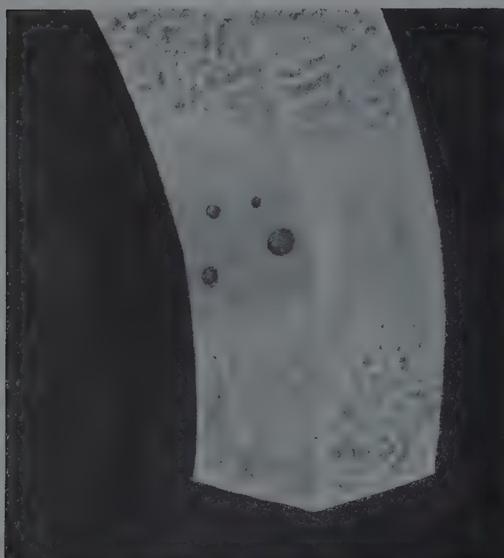


FIG. 14.—The endothelial cells and the endothelial craters (Hassal-Henle Warts).

The following is the technique for finding the cells: the structures have no reflecting surface behind them and can be appreciated only by light reflected from their own posterior limiting surface. They are perceived in mirror light over but a small area. This area is too small to be covered by both objectives, and accordingly the cells are observed by one eye only. Let us work with light coming from the left and with a wide angle between the microscope axis and the illuminating axis to obtain a good separation of the prism surfaces. We move the beam and microscope till we catch the bright dazzle from the lamp. Displace the beam slightly to the left till the edge of the dazzle is just in the field. Now focus down to the endothelial surface of the prism till a yellowish shagreen surface is seen. A still more exact focus will reveal the cells. With ocular 2 and objective A 2 they look like small circles, but with A 3 we can see that they are hexagonal. The appearance is that of a honeycomb, and the colour is similar. Here and there among the cells the craters are obvious. The appearance of the cells and craters at the back of the prism is shown in Fig. 14. A beautiful drawing will be found in Gallemaert's book.

When examining for the endothelial cells a bright blur will be

seen to the right of the prism. If we focus down into this blur we shall find that it becomes rectangular and has a silvery sheen. It is the catoptric reflection of the diaphragm of the illuminating lens from the corneal surface. The image is situated in the anterior part of the lens. *The image does not appreciably move with displacement of the light-arm*, and in this manner can be identified with ease. In a certain position we can focus the bright image of the glowing filament in the centre of the diaphragm. These and other catoptric images are fully described in Koby's book on the slit-lamp, and are worthy of study.

Occasionally two crenellated rings are seen reflected from the corneal surfaces. These are the images of the orifices of the objectives.

The Conjunctival Prism.—Using the narrow beam we can obtain a definite prism in the limbal region. Its deeper aspect is ill-defined because the sclera is not wholly opaque. The superficial portion is perfectly transparent, and below this layer the conjunctival vessels form a network ending at the corneal margin in a series of arcades. A deeper network of vessels is constant at the limbus, and represents the superficial episcleral circumcorneal ring, fed from the anterior ciliary arteries. The superficial vessels move freely over the deeper, and both sets anastomose at the edge of Bowman's membrane, which does not reach the margin of the cornea. According to Salzmann these vessels in a meridional section of the limbal region form a triangle whose apex abuts upon the edge of Bowman's membrane. The conjunctival prism is useful in localising the depth of tumours in this region, and in estimating the thickness of the conjunctiva.

The sclera here forms a series of radial palisades which are opaque in comparison with the transparent corneal tissue between them. In old age the opacity is more marked.

The limbal lymphatics are opaque-looking white strands considerably larger than the blood vessels and less numerous. We have seen them best in a case of acute glaucoma.

The Visible Circulation.—This interesting phenomenon was first noted by Coccius in 1852 and again by Friedenwald in 1888. The former observed the limbal vessels with a system of lenses, the latter with the ordinary loupe. Using the focal illumination of a half-watt lamp and a simple loupe, the visible blood stream can be appreciated not only in pathological corneal vessels, but also in the limbal circulation of a perfectly normal person.

Naturally with the better focal light of the slit-lamp and the higher magnification of the Zeiss-Czapski microscope the examination is simplified. It is necessary to view the vessels by transmitted light. The observation is easier in corneal vessels than at the limbus. Focus the light upon the iris and the microscope upon the corneal vessels. Select a thin-walled vein and a stream of globules will be seen streaming along the vessel. In the case of the limbus: focus the light upon the sclera and so adjust the position of the axis of observation that the light is reflected back through the vessel chosen. It is sometimes impossible to see any movement in the vessels. This is either because the blood vessel is too thick-walled, or on account of the extreme rapidity of the blood current; if the motion of the corpuscles exceeds a certain limiting speed they are invisible. It seems probable that the globules seen are the actual red corpuscles. It has been urged that the magnification used is insufficient to resolve the actual erythrocytes, but the living cell may be considerably larger than the dead, and the motion makes them easier to see. Often in an old case of interstitial keratitis we find atrophied vessels carrying a very slow stream, and in some cases the corpuscles can be seen at rest. In a private discussion Vogt expressed the opinion that the globules seen with the slit-lamp were the actual blood cells.

Slit-lamp examination confirms the views of Krogh, who finds that the regulation of the circulation is not wholly dependent upon the contraction and relaxation of arterioles, but is governed by the capillaries themselves. He discovered that the Rouget cells functioned as pseudo-muscular tissue. It is suggested that an excess of pituitrin in the blood stimulates these cells, closes the capillary, and cuts off the blood stream. When the pituitrin effect has lapsed the capillary relaxes and the blood stream is re-established. Observation with the slit-lamp reveals this intermittent flow. In the smallest capillaries the stream is not continuous. It suddenly stops and a neighbouring vessel takes up the work; this finally ceases, and the original vessel resumes its function. In some vessels there is no constant flow, but blood cells are suddenly projected with great velocity like shots from a machine gun. In a lateral branch joining two collateral vessels the current is frequently reversed, reacting to the varying pressure in the parent vessels.

CHAPTER IV

LOCALISATION AND MEASUREMENT

HITHERTO the ophthalmic surgeon has had no accurate method of making measurements of depth. The ophthalmoscope works in two dimensions and the older modes of focal illumination were too crude to supply the third dimension, and with the third dimension, localisation in space. Until the slit-lamp was introduced our estimates of the actual position of an object in the eye were at best good guessing. We are now able to localise with extreme precision and to make accurate measurements along the optical axis of the eye. This advance is of incalculable value, the most precious gift of the slit-lamp. Professor Vogt told his students at the end of his slit-lamp course at Zürich that, "if they had learned to localise and nothing else their journey had been well rewarded, but that if they had failed to master the main facts of the technique of localisation their time had been wasted." The power to localise is the chief feature of the slit-lamp, and the beginner should endeavour to become so proficient that accurate localisation is a mere part of observation, entirely automatic and intuitive.

Localisation by Focus.—This method is not very accurate, but is useful under certain conditions. It is very difficult to decide whether an œdema of the cornea is epithelial or endothelial, but it can generally be accomplished by focusing an object, say a droplet, upon the corneal surface and comparing the sharpness of the focus with that of the details of the œdema. If we have to focus in to get the œdema distinct, then it lies at a deeper level than the epithelial object, and is endothelial. We can now reverse the process by focusing say a deposit of K.P. on the posterior surface and comparing the relative sharpness with that of the œdema.

Localisation by Inspection.—The fact that the microscope gives a stereoscopic image allows us to make an estimation of the relative positions of objects by mere inspection, and when we get accustomed to the magnification of the lenses employed we obtain an absolute

conception of size. For this reason it is wise to work mainly with one magnification, and the most commonly used is 20, that furnished by ocular 2 and objective A 2. The expert with the slit-lamp is always localising unconsciously by inspection and by Vogt's method to be described later.

Localisation and Measurement with the Micrometer Eyepiece.—The micrometer scale is fitted to ocular 2. The best form is a simple linear scale divided into tenths. In ordinary clinical work its chief use is to make measurements laterally; for example, to record the extent of an ulcer or nebula on the cornea. We approximate the scale to the object and read off the number of divisions on the scale that cover the object. Divide this number by the magnification in use and the quotient is the absolute measurement in millimetres. Thus if the width of the corneal prism be twenty divisions, and we are using ocular 2 and objective A 2, a magnification of 20, the actual width of the beam of light is 1 millimetre.

The micrometer eyepiece can be used for depth measurements. Thus, for example, we wish to measure the thickness of the cornea. We note the number of divisions that cover the proximal section of the corneal prism, the distance from edge *bd* to edge *fh*. This is not the real thickness of the cornea, for the surface is observed in perspective and only its projection is actually measured. To make the figure an absolute one it is necessary to know the angle between the microscope axis and the axis of the lamp. This can be read off on the arc of a goniometer which can be supplied with the instrument. Knowing the angle and the base length of the triangle, we can solve the triangle and compute the perpendicular which is the apparent thickness of the cornea. A correction for refraction gives the actual thickness of the cornea. It is obvious that this method can have no place in the routine examination of a patient, but it is useful for research, and with it Vogt has made valuable observations upon the growth of the lens and the thickness of the lamellæ. Much practice and plenty of time are necessary to obtain any degree of accuracy.

Measurements with Ulbrich's Drum.—Ulbrich's drum is useful to measure the depth of the anterior chamber and the thickness of the lens; we have also employed it to estimate the depth of the retrolental space. The method is hardly capable of sufficient accuracy to measure the thickness of the cornea.

The technique to measure the depth of the anterior chamber

requires care and considerable practice. Our own method is as follows: the eye of the patient is so adjusted that the endothelial cells are visible in the centre of the cornea. The microscope is sharply focused upon these cells and the drum slipped back to zero. Or the drum can be placed at zero and the cells focused by hand movement of the microscope, or with the mechanical stage if one be fitted. We now bring the epithelial cells on the anterior lens capsule into sharp focus and read the drum scale. The figure may be taken as the absolute distance, for the corrections for refraction are small, indeed much smaller than the experimental error. This measurement is repeated several times and a mean taken of the readings. To correct for refraction it is necessary to measure the corneal curvatures with a keratometer and then enter a table for the correction. This is quite unnecessary and also impossible in the outpatient room, there is not time for such academical minutiæ. Another procedure is to measure from the line *fh* to the surface of the iris, but this introduces an error in that the anterior chamber is shallower at the pupil margin than in the centre.

In focusing back to the lens shagreen the light must be focused in simultaneously, because the whole secret of accuracy is fine focus. Using the cells the focus can be made much more precise than if the iris surface and parts of the prism be used. The chief source of error lies in getting a sharp focus, and also in keeping to the centre of the cornea. Using the epithelial cells we have the best object available and the result will be the deepest part of the anterior chamber. We have obtained 3 millimetres as the depth of the anterior chamber by this method, using a boy of eighteen as the subject. With the same patient the thickness of the lens was 3 millimetres.

To measure the lens depth we employ the narrow beam and make a successive estimation of the focus of the anterior capsule and the posterior capsule, again making the simultaneous adjustment of light and microscope.

Within certain limits Ulbrich's drum is useful in clinical work, but unless the patient have good fixation power the result cannot be accurate.

Vogt's Method of Localisation.—The most valuable, the most rapid, and the most practical method of localisation is that described by Vogt. A translation of his paper by the author will be found in the *British Journal of Ophthalmology*, vol. viii, p. 117.

When the beginner has become expert in simultaneously focusing the beam of light and the microscope upon the edges *bd* and *fh* of the corneal prism, he is in a position to begin to localise in the cornea by Vogt's method. The thickness of the cornea in the centre is about 0·8 millimetre; this is magnified 20 times, giving an apparent breadth of 16 millimetres, but we must almost halve this because of the angle of the section. So we can say that viewing the corneal prism with ocular 2 and objective A 2 we have an actual line of 8 millimetres along which to localise. This can be divided into eight imaginary parts by eye alone, each having the apparent length of 1 millimetre, but the real length of one-tenth of a millimetre. Thus if an object in the cornea appears to be 2 millimetres from the corneal surface it is actually one-fifth of a millimetre.

We focus the object we wish to localise and swing the lamp-arm till the object *lights up* in the proximal surface of the prism. Let us imagine that it first becomes illuminated on the line *fh*, then we know that its actual position is on the posterior surface of the cornea. It lights up on the line *bd*; its actual position is on the outer surface of the cornea. It is first illuminated 2 millimetres from the line *fh*; its actual position is four-fifths of a millimetre from the epithelial surface. It will be at once seen that Vogt's method is exceedingly accurate, and it will also be obvious that the method cannot be applied with a slit-lamp in which the light-arm is rigidly bound to the microscope. Still greater accuracy can be attained if instead of using the broad beam and prism we select the narrow beam. This should always be employed for the final localisation.

The beginner can practise on the pig's eye localisation by Vogt's method. A little chalk can be sprinkled upon the cornea and the particles localised. The pig's cornea after enucleation is full of small opacities which serve for objects, and there is often some pigment upon the posterior surface which can be localised. It is absolutely essential to become expert in localisation, otherwise the slit-lamp loses most of its value and the use of the combined apparatus becomes mere microscopy.

CHAPTER V

ABNORMALITIES OF THE CORNEA

CHANGES in Thickness.—Under certain conditions the cornea may become abnormally *thin*, and this change may be regular as in conical cornea or quite irregular. Thin areas in the cornea are common after the patchy deep infiltration that occurs in strumous keratitis, and these may be quite invisible by ordinary methods of examination, and may not affect the corneal surface. Examination with the narrow beam at once detects any alteration in thickness or abnormal contour of the anterior or posterior surfaces. Examples are shown in Fig. 15. The cornea is thickened in keratitis profunda and especially in interstitial keratitis.

FIG. 15.—Alterations in the thickness of the cornea in an old case of strumous keratitis profunda. In the left-hand drawing a patch of sclerosis is seen deep in the cornea.

The normal cornea must vary considerably in thickness, for the measurements given vary from 0·5 to 0·8 mm.

Abnormalities of the cornea may be considered under three heads: those affecting the *epithelium*, the *stroma*, and *Descemet's membrane with the endothelial cells.*

In the various forms of *bullous keratitis* the whole layer of epithelium becomes detached. An example is shown in Fig. 16. Here there is a localised pannus in a case of recurrent erosion. The drawing clearly shows that the vessels are situated immediately under the epithelium, and that this layer is peeling off, forming a large bulla. Every case of this nature should be examined with the slit-lamp, for this method alone reveals the extent and character of the change. Another example is seen in Fig. 17.

Vogt has described a condition of the cornea which he calls

FIG. 16.—A recurrent erosion of the cornea after a trauma. The epithelium is separated into a bulla. A leash of vessels lies under the epithelium, and shows the localisation of a pannus.

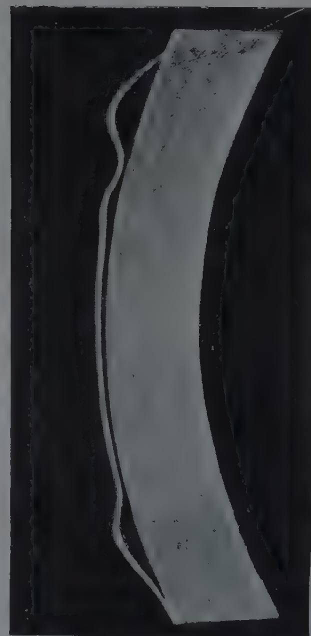


FIG. 17.—Bullous keratitis. It will be noted that the separation of the epithelium is much wider than the area of the actual bulla.

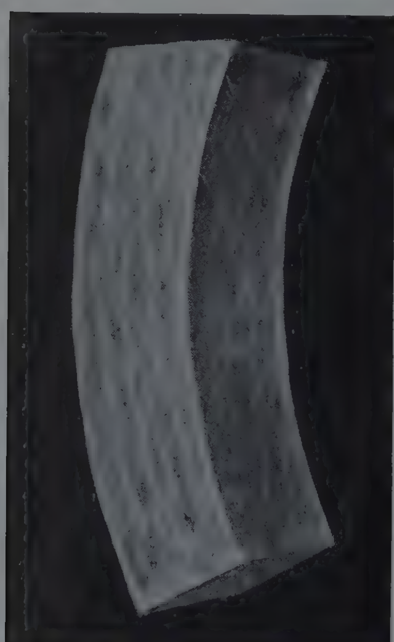


FIG. 18.—Keratitis epithelialis superficialis (Vogt).

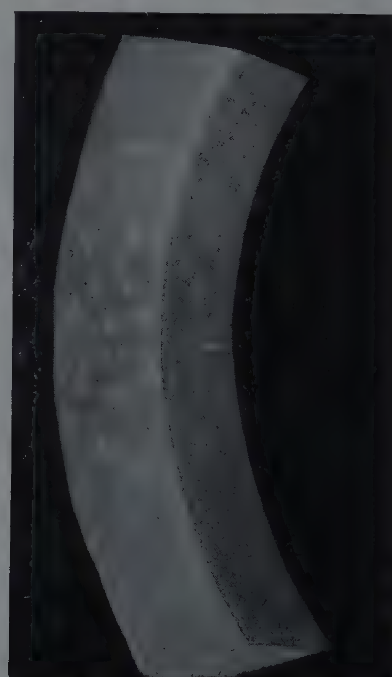


FIG. 19.—Rosacea of the cornea.

keratitis epithelialis. An example is shown in Fig. 18. The patient was a male aged thirty-two, who for some months had suffered from severe photophobia and lachrymation. There was little conjunctivitis and no ulceration of the cornea. When the pupil was dilated and the eye examined with the focal light of a half-watt lamp and a loupe, it was noted that the cornea seen against the dark pupil showed a billowy cloudy appearance. The slit-lamp showed that the surface of the cornea was iridescent and that it was covered with tenuous plaques of a slightly opaque nature, which reflected light more strongly than the neighbouring corneal surface. It is important to recognise this disease, because it causes great discomfort and inability to work, and is liable to be regarded as an ordinary case of chronic conjunctivitis. The changes cannot be discovered by ordinary illumination with diffuse light. This patient recovered only when all irritating lotions such as zinc sulphate had been discontinued, and normal saline substituted.

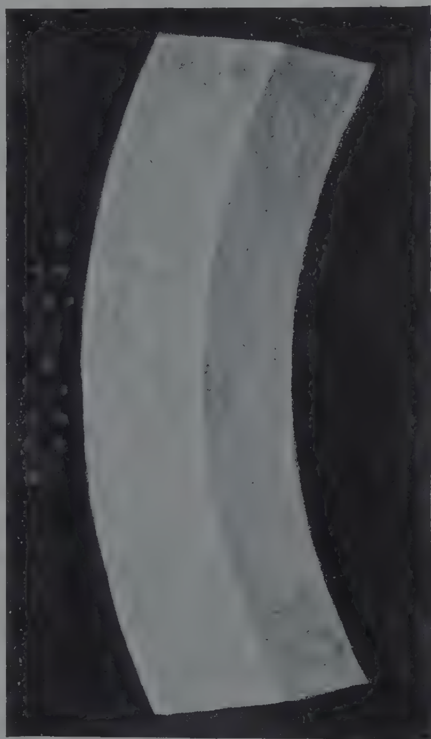


FIG. 20.—Keratitis punctata superficialis.

Rosacea of the Cornea.—In some cases of facial rosacea the cornea suffers. Seen with the slit-lamp soft-looking ill-defined foci are confined to the epithelial layer. The condition resists treatment and causes much irritation. It will persist for months until the skin is treated. (Fig. 19.)

Keratitis punctata superficialis.—The appearance of the cornea in this fairly well-known disease is seen in Fig. 20. In this case no change had taken place in eighteen months and no discomfort was experienced. In the centre of the cornea there is a collection of small white dots. These are seen with the slit-lamp to be situated in the epithelium. They are opaque, and in contradistinction to the rosacea dots, sharply defined. The epithelium examined in light reflected from the posterior lens capsule was seen to be vacuolated.

Herpes ophthalmicus not only gives rise to iritis but may occasionally cause a characteristic keratitis. In one case with severe iridocyclitis and keratic precipitates, there was a localised deposit in the cornea of white elongated dots. These were detected with the loupe, and are shown in Fig. 21. Under the slit-lamp a well-defined layer of opaque white deposits like rice grains were seen under the epithelial layer. In addition to the deposits seen on the prism others are visible illuminated by light reflected from the iris. In Fig. 22 the subepithelial foci are seen on the left, whereas on the right there is K.P.

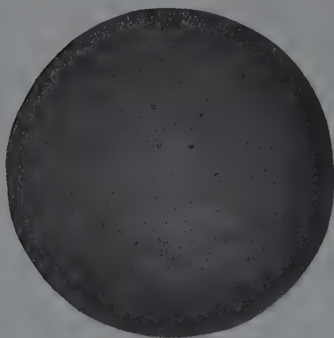


Fig. 21.—Changes in the cornea in herpes of the 5th nerve seen with the loupe.

Fig. 22.—The same condition seen with the slit-lamp. It will be noted that the rice-grain-like dense, white, opaque foci are situated in the anterior quarter of the cornea under Bowman's membrane.

Fig. 23 shows the effect of a depilatory fluid containing barium hydroxide upon the cornea. The effect of lime is similar. The whole cornea was white and opaque. The epithelial surface of the corneal prism was covered with dense shining plaques, and the area seen under iris light showed a fine network of white lines with nodes at the intersections. These white lines have been described by Koby in cases of lime burn. They were not, as

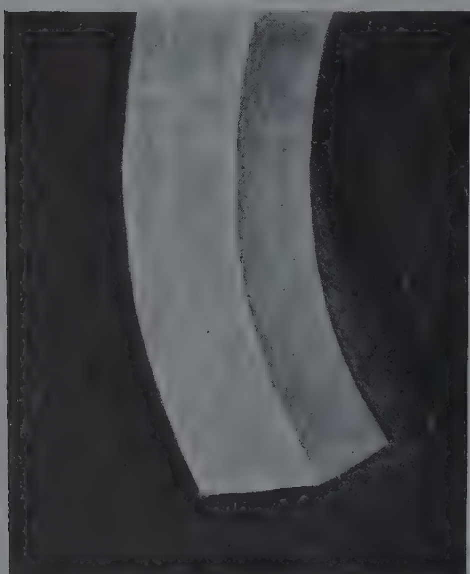


Fig. 23.—The cornea after cauterisation with barium hydroxide. The epithelial surface is covered with glittering white plaques. A fine network of filaments with nodal points is visible superficially in the cornea. Some exudate is adherent to the posterior corneal surface.

in Fuchs' filamentary keratitis, twisted fibrillæ lying loose on the corneal surface, but were definitely within the cornea. An exact examination was difficult on account of considerable photophobia.

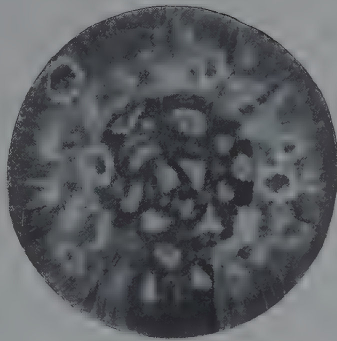


FIG. 24.—Calcification of the cornea after 5th nerve herpes.

Calcification of the Cornea.—The appearance under the slit-lamp of a case of corneal calcification following herpes ophthalmicus is shown in Fig. 24. There was a six-years history of iritis and keratitis and an iridectomy had been performed by Mr. Maddox.

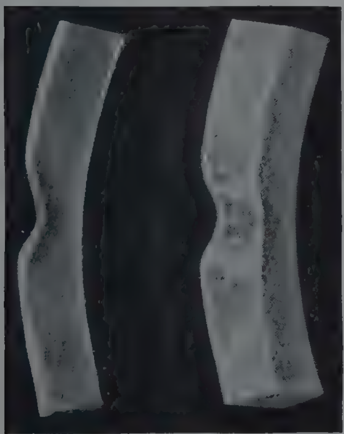


FIG. 25.—Ulceration of the cornea seen with the narrow and broad beam. The dark area shows the penetration of fluorescein. In a short time the whole corneal parenchyma was infiltrated with the stain.

Ulceration of the Cornea.—The slit-lamp is essential in the examination of a corneal ulcer. With the narrow beam one can make section after section and so obtain an exact picture of its depth and configuration. It is possible to follow the course of the ulceration, to see the first stages of vascularisation, and trace the process of healing. Fig. 25 shows a corneal ulcer as seen with the broad and the narrow beams. The darker area shows the penetration of fluorescein. Fig. 26 shows the heaping up which has followed the removal of a foreign body.

FIG. 26.—Shows a heaping up of corneal tissue after the removal of a foreign body.

Keratitis profunda.—This term covers a large number of conditions, many of them little understood and most of them unclassified. It includes localised areas of deep keratitis such as sclerosing keratitis; the patchy type which we associate with strumous conditions, and interstitial keratitis itself.

Acute Keratitis profunda.—Quite recently we saw a case which by ordinary examination appeared to be an example of superficial keratitis. There was a short history of failing sight in one eye in an elderly woman. The centre of the cornea was slightly hazy, and there was a little pericorneal injection. The slit-lamp showed

that the cornea was at least double its ordinary thickness, with extensive loss of transparency. Complete recovery followed.

Keratitis disciformis.—There would appear to be a group of deep inflammatory conditions of the cornea all of which have certain characteristics in common; in some there is a definite condensation into a more or less well-defined disc, which may be central or eccen-

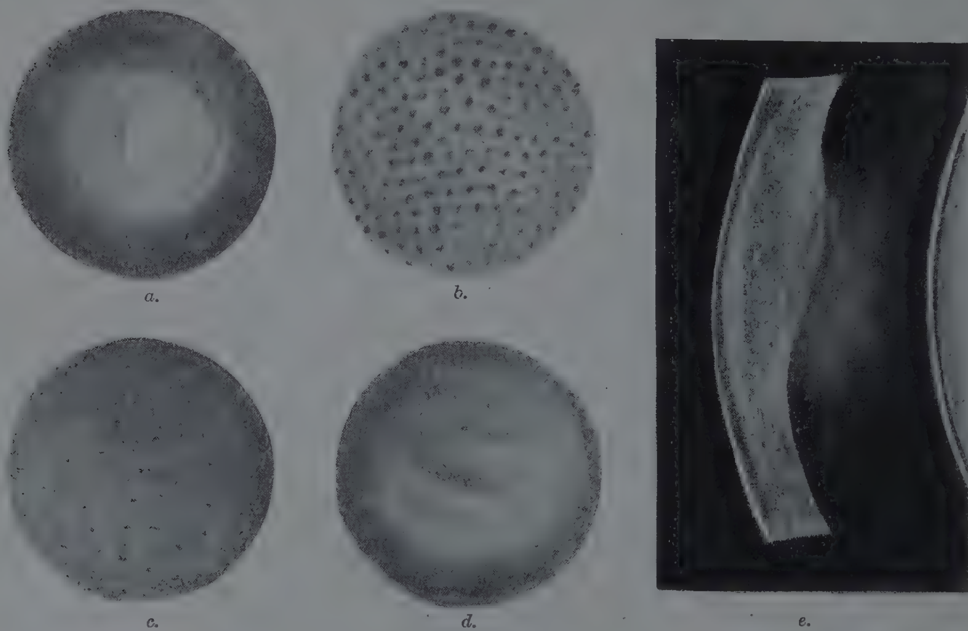


FIG. 27.—Discoid keratitis.

(*a*) View with the loupe, showing an apparent anterior bulging of the cornea.

(*b*) The endothelial surface seen with the slit-lamp, showing the complete absence of visible cells, but a large number of craters.

(*c*) The stippling of the corneal epithelial surface.

(*d*) The endothelial shagreen seen with the loupe.

(*e*) The slit-lamp section, showing the situation of the opacity and the inward bulge. The diffuse white area apparently within the anterior chamber is the opacity seen without the prism area by diffused light. The lens is seen on the right.

trically placed, in others the inflammatory focus is not sharply defined.

The disease almost invariably follows an injury to the cornea which may be trivial in nature. We find a localised focus of infiltration, generally of a yellowish hue, deep in the stroma, but separated from the epithelial layer by a zone of perfectly clear, normal stroma. The cornea shows a general thickening and its posterior surface cannot be defined owing to the opacity in front of it. Over a wide area round the focus the endothelial cells are invisible, but the

"craters" are exceedingly numerous, in fact in some cases the whole endothelial surface consists of craters. There is a strong tendency towards recovery, and as the cornea clears up the endothelial cells again become visible. The disappearance of the cells is not due to corneal haze, for it is seen well away from the opacity where the tissue is not infiltrated and is perfectly clear. This observation may have no value, but it has been made in several cases both with and without definite discs. It seems probable that a careful study of the behaviour of these cells in cases of corneal inflammation may yield facts of clinical importance. None of the cases show vascularisation of the cornea, and there was no K.P.

A case of disciform keratitis is shown in Fig. 27. The notes attached to the drawing are as follows: Miss N. G. G., aged twenty. Foreign body removed from cornea seven weeks ago. Gradually increasing mist. The eye is not injected and there is no vascularisation. In the centre of the cornea there is an opacity taking the form of a definite disc with somewhat ill-defined edges. This is shown in Fig. 27/*a*. The endothelial shagreen can be seen over a large area all round the disc. It can be made out with a simple loupe with the aid of a half-watt lamp. No endothelial cells can be seen, except at the periphery of the cornea, but the craters are very numerous all over the cornea. They are shown in Fig. 27/*b*. The epithelium over the affected area is stippled, covered with pointed elevations, as shown in Fig. 27/*c*. Fig. 27/*d* shows the endothelial shagreen as seen in mirror light with an ordinary loupe. The "section" shown in Fig. 27/*e* defines the exact position of the opacity. It will be noted that the internal surface of the cornea has an inward bulge, and that it fades off into the general opacity which off the prism is illuminated by iris light. This prominence was noted with the loupe as shown in Fig. 27/*a*, but it gave the appearance of a bulge on the anterior surface of the cornea. This case gradually improved, and when last seen the cornea was almost clear and the endothelial cells were visible.

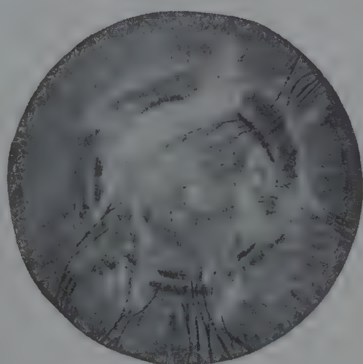


FIG. 28.—Case simulating keratitis disciformis. Opacity superficial in corneal stroma with deep vascularisation.

The condition shown in Fig. 28, although superficially one of

discoid keratitis, presents several points of dissimilarity. Again there is a history of a trivial accident, and a central disc which in the main is well defined. The cornea shows a deep vascularisation, but the opacity, as shown in Fig. 29, is situated in the anterior third of the corneal stroma. It is hard-looking and densely opaque. It has obviously contracted, umbilicating the cornea. This case has not shown the slightest tendency to recovery, and the slit-lamp appearance forbids any hope that the opacity will become transparent. We obviously have a mass of fibrous tissue just under Bowman's membrane, separated from the epithelium by a narrow clear zone.


FIG. 29.—The same cornea in optical section.

Interstitial Keratitis in its typical form would appear to be due to syphilis, and in our own experience to congenital syphilis.

Examination with the slit-lamp shows that the infiltration begins as a nodular opacity in the posterior part of the cornea, and spreads forward till it reaches the anterior third. Here the process ends; and even in the most acute cases, where the cornea appears to be perfectly opaque, we have found a clear transparent zone under the epithelium. It is possible to watch the blood vessels entering the cornea from the periphery in the form of loops. At first only the deeper parts are vascularised, but in the later stages the conjunctival arcades send loops into the cornea which can be seen eventually to anastomose with the deeper vessels.

Generally the cornea is now greatly thickened, and Descemet's membrane becomes folded. The folds are parallel or seem to radiate fanwise from a centre. The posterior surface of the cornea soon shows a definite sclerosis which greatly increases its reflecting power. It is possible for a case to recover so completely that no trace whatsoever can be seen with the slit-lamp; we have seen patients whom we have treated for interstitial keratitis, showing all the characteristic features with the slit-lamp, make this perfect restoration in a few months. With the majority this is not the case.

The posterior sclerosis is permanent. The back of the prism is more obvious than the front, and has a white granular sheen; the edge *eg* is sharply defined and even after twenty years there may be vessels carrying an active circulation.

It is a mistake to suppose that the thin lines seen in a cornea that has suffered from interstitial keratitis are in the main the mere channels which held the vessels now atrophied. We have examined patients who have suffered from interstitial keratitis fifteen years previously, and have been astonished to find an active circulation flowing through thin-walled atrophic vessels. In some the stream is rapid, in others slow; in a few it has ceased, leaving groups of corpuscles permanently stranded in an otherwise empty vessel.

True syphilitic interstitial keratitis presents a typical picture which with the aid of the slit-lamp cannot be mistaken for any other condition whatsoever. The infiltration of the cornea is fundamentally associated with the posterior layers of the corneal stroma, and though, when the inflammation is at its height, the more anterior zones may participate in the process, yet this is secondary to the main focus in front of Descemet's membrane. Although in the acute stages the cornea is greatly thickened, it in most cases returns to its normal contour and depth. How different is the picture in the strumous type! Here the foci of inflammation may be found in any part of the cornea, deep and superficial. They are generally localised and do not involve the whole cornea. The vascularisation is as often from the conjunctival as from the deep circulation, and it is quite unusual to find the great thickening of the cornea which is the rule in the acute stages of the syphilitic disease. The final result is quite different. Generally the cornea is very unequal in thickness and in places very thin, perhaps a fourth of its normal thickness, and the high reflection of the posterior surface of the cornea is not seen.

Fig. C, Plate I, was painted from an old case of interstitial keratitis. The section shows that the sclerosis is confined to the posterior layers, and that the main portion of the cornea is transparent and free from vessels. The prism is seen in Fig. D, Plate I. It shows the highly characteristic appearance of the endothelial surface, which has the typical opaque, granular, slightly yellowish, appearance. It stands out brightly in contrast to the epithelial surface, which is dull by comparison.

In two cases of interstitial keratitis we have found cells in the aqueous of the other apparently unaffected eye. In one of them we detected a peripheral choroiditis, and soon the full picture of interstitial keratitis. It would appear, therefore, that we may be able to foretell

FIG. 30.—Sclerosing keratitis. Localised opacity situated in the posterior part of the cornea with a deep vascularisation. The broad streak on the right side of the cornea is a light reflex.

the onset of the inflammation in the second eye by an examination of the aqueous, the retro-lental space, and the vitreous. In several cases we have detected anterior choroiditis antedating the keratitis, and the slit-lamp will give us still earlier warning.

Keratitis profunda marginalis (Sclerosing Keratitis).—An example of this condition in a woman of sixty was associated with a septic toe-nail, and with gall-stones. The eye had been inflamed for twelve months. In the N.W. sector close to the periphery there was a deep-seated yellowish opacity and away in the S.E. sector some superficial bullæ. The cornea is shown in Fig. 30, and the section in Fig. 31. The opacity is seen to be sharply localised in the posterior third of the cornea, and to be surrounded by perfectly normal tissue. Sclerosing keratitis is always of this type and in this situation. The vascularisation is confined to the sclerosed area.

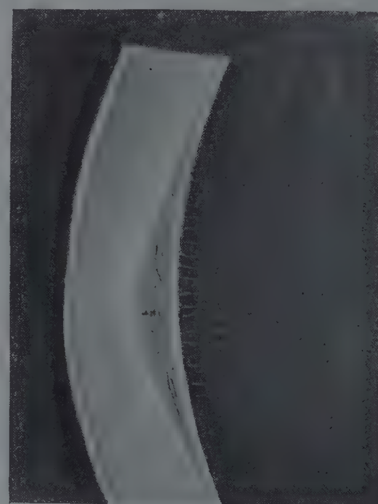


FIG. 31.—The same in optical section.

Descemet's Membrane.—Folds of this membrane are very common, and may be either permanent or transient. *Permanent folds* of the radial type are left after a central keratitis. Fig. 13, already mentioned, was taken from an old case of iridocyclitis which had ended with cataract and disorganisation of the eye. It is evident that at one time there had been a central keratitis which affected the whole thickness of the cornea. Centripetal contraction has caused radial plication of both Bowman's and Descemet's membranes.

FIG. 32.—Central radial folding of Descemet's membrane in a case of long-standing central keratitis.

Fig. 32. This example of radial folding was discovered in a refraction case during the routine slit-lamp examination. There was a history of some eye affection about thirty years previously.

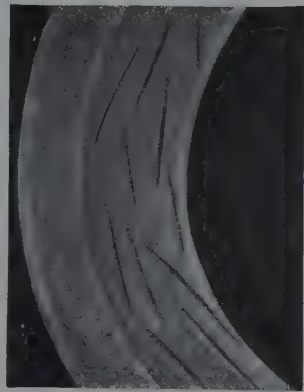


Fig. 33.—The transient folds of Descemet's membrane frequently seen after operations upon the globe.

Transient Folds are common after almost any operation or accident which opens the anterior chamber, and in many inflammatory diseases of the cornea. They are often present after contusions of the globe, and in conical cornea. They have a double contour with a bright, silvery border. The typical appearance of these transient folds is shown in Fig. 33, which was taken from a patient upon whom a preliminary iridectomy had been performed a week previously. In a few days they had all disappeared. After a cataract operation we occasionally get a series of vertical folds which radiate fan-wise from the region of the section. This is the condition known as striate keratitis. Alphabet keratitis is another form of irregular folding of this membrane.

Calcareous Descemetitis.—We recently examined a medical man who exhibited a most interesting change in Descemet's membrane.

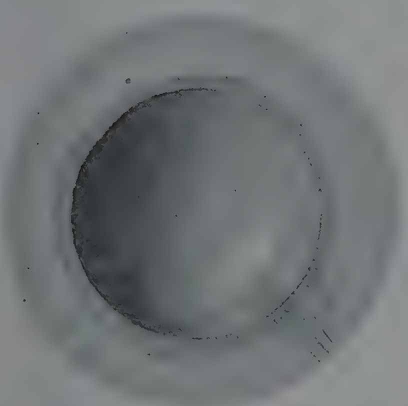


Fig. 34.—A case of opacity in Descemet's membrane and deep corneal layers.

For some six months he had been troubled with recurrent injection of the right eye. Eventually he noted a white spot on his cornea. Examination with the loupe showed a dead-white opacity midway between the centre and periphery of the cornea in the S.E. sector. This opacity was fed by a vascularisation which covered an area wider than the opacity. The appearance is seen in Fig. 34. The slit-lamp showed that the opacity was situated in the most posterior layers of the cornea if not in Descemet's membrane itself. The vascularisation was confined to this deep zone. The section of the cornea is seen in Fig. 36. This demonstrates the situation of the opacity, and the normal stroma anterior to it.

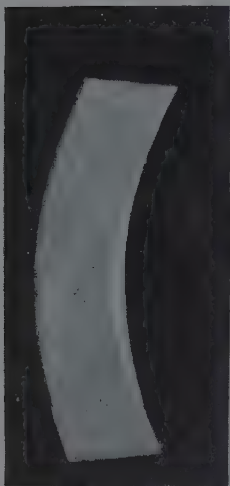


FIG. 35.—The same in optical section.

The opacity itself, viewed *en face* with the broad beam, consisted of an aggregation of circular and crescentic deposits of a white amorphous substance looking like chalk; it is shown in Fig. 35. A careful examination of the cornea revealed widespread alteration in the region of Descemet's membrane. There is a well-marked increase of reflective power in the posterior surface suggesting a generalised sclerosis of the deepest corneal zone, perhaps an alteration in the texture of Descemet's membrane. The endothelial cells were irregular in size but clearly visible. The endothelial cells in the apparently healthy eye, shown in Fig. 37, were also irregular in size, some of them being double the size of the others, which were normal. The changes in Descemet's membrane were obvious when the cornea was examined in light from the posterior capsule.

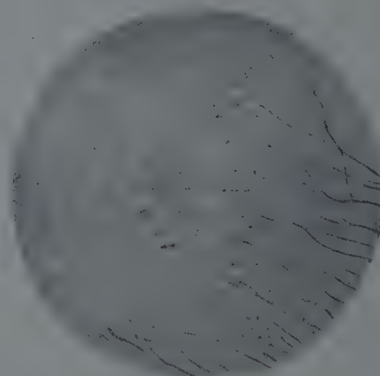
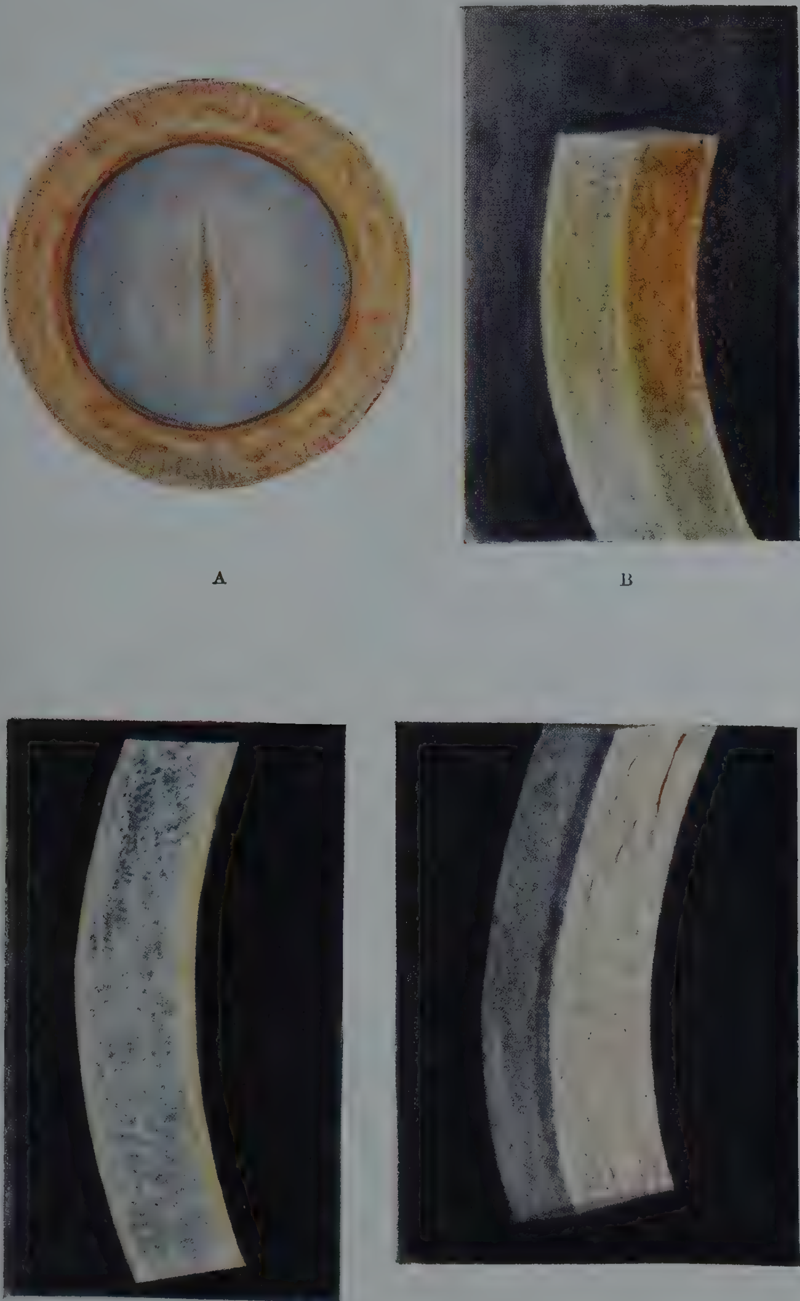


FIG. 36.—An enlarged *en face* view of the opacity, showing a calcified structure.

The Beaten-silver Appearance of Descemet's Membrane.—We recently had the opportunity of examining a woman of thirty who showed this change, which has been described by Vogt and extensively studied by Graves (see *The British Journal of Ophthalmology*, vol. viii, p. 502). She complained of a slight dimness of vision. With a plus 20 lens behind the ophthalmoscope mirror, the whole cornea was finely stippled, and one formed the opinion that the change was deep in the cornea. When the beam of light was moved over the surface of the cornea, bright "glints" were seen on the posterior surface of the prism, both with the narrow and broad beam. The cornea was now examined with the pencil of light furnished by the pin-hole diaphragm reflected from the posterior lens capsule.

FIG. 37.—The endothelial cells in the opposite eye of the same case. The craters are well shown, and the irregular size of the cells, which is abnormal.

PLATE I



A B

C D

A.—Kruckenberg's spindle seen with the loupe. B.—Kruckenberg's spindle seen in the corneal prism. C.—A section of the cornea in an old case of interstitial keratitis. D.—The corneal prism in the same case of interstitial keratitis. Note the strongly reflecting yellowish endothelial surface.

The whole posterior corneal surface was in appearance exactly like beaten silver.

Pigmentation of the Cornea.—Areas of pigmentation may be found in the cornea, especially in old age. They are generally situated at the periphery. Vogt has made an exhaustive study of senile pigmentation. In addition to these diffuse deposits there are others which have a definite shape and location.

Kruckenberg's Spindle is a deposit of pigment which forms a diffuse yellowish-brown coloration in the centre of the cornea with a spindle-shaped condensation in the vertical diameter. It has so far been observed only in myopes. The abnormality is figured in Plate I, Fig. A, viewed with the loupe under diffuse lateral illumination. Plate I, Fig. B, is the view obtained with the slit-lamp under a magnification of 20. We note that the colour is due to an aggregation of pigment rings upon the posterior surface of the cornea, probably upon or in Descemet's membrane. In Fig. 38 the deposits are seen under a magnification of 35. The endothelial cells were clearly seen and were normal. Some of the rings contained a central dot. The drawings are probably not absolutely accurate, for they were made from memory from a case shown by Mr. Viner at a meeting of the Ophthalmological Section of the Royal Society of Medicine held at the Westminster Hospital. This case was the exact counterpart of one demonstrated by Professor Vogt at his Slit-lamp Course at Zürich.

FIG. 38.—An enlarged view of the elements which form the opacity in Kruckenberg's spindle. Each consists of a ring of pigment. Some of the rings contain a central dot. (This drawing was made from memory, and may not be accurate in detail.)

Mr. Clegg in 1924 showed a case to the Manchester Meeting of the Northern Ophthalmological Society in which there was in each eye a somewhat similar appearance, a central area of pigmentation. In each eye the right side of the patch had a sharp, roughly vertical margin, whereas the left side was diffuse. In this case the pigmentation was not due to a golden deposit in the cornea, but to a definite collection of pigment granules upon the posterior surface of the cornea. These were not circular, and had

not the central lucid interval that characterised Mr. Viner's case.

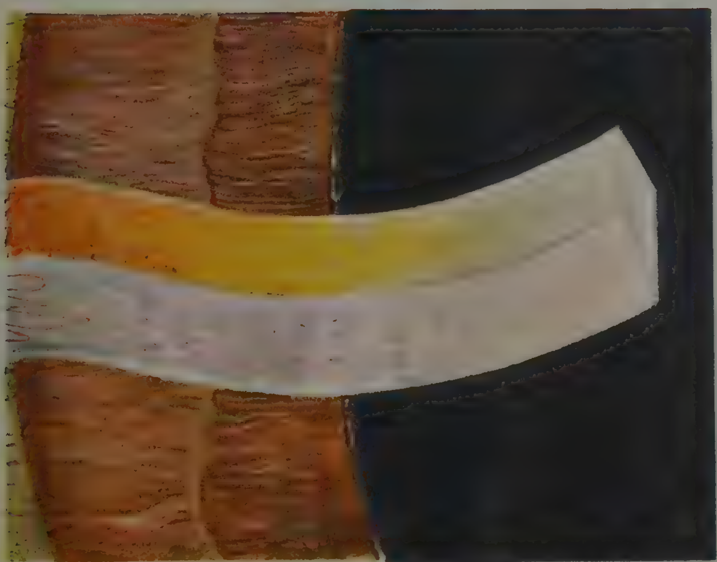
Hudson's Brown Line.—This line is not infrequently seen in old scars in the cornea. It is a superficially placed wavy line of a yellowish-brown colour, generally running in a horizontal direction. It can be seen with the loupe.

Stähli's Line.—This is a superficial thin sinuous line running horizontally across the cornea about half-way between the centre and the inferior limbal region. It is yellowish brown in colour and may be branched. It is supposed to be situated in the neighbourhood of Bowman's membrane. It is difficult to see and calls for good illumination and accurate focusing.

The Kayser-Fleischer Ring is occasionally found in Kinnier Wilson's disease, hepato-lenticular degeneration. It takes the form of a golden ring situated in the corneal periphery. At the limbus it is brown, becoming golden in the cornea and fading off into yellow on its central aspect.

Owing to the kindness of Dr. Stanley Barnes, Physician to the General Hospital, Birmingham, we were able to examine two cases of this disease, one of which showed the characteristic ring. A full account of the cases will be found in *Brain*, vol. xlviii, part 3. The appearance seen is shown in Plate II. When the light of a half-watt lamp was thrown obliquely on to the iris through the corneal periphery so that it passed through a considerable thickness of the cornea at its lowest part, we noted that the iris glowed as though the setting sun were shining upon it. The examination, owing to the child's constant contractures, was very difficult and this probably accounted for our inability to see the actual ring with the loupe. The golden glow is seen in the lower part of the iris. The child had to be supported at the slit-lamp by two nurses, and it was an arduous matter to carry out the observations. The back of the corneal prism at the limbus showed a golden-brown granular deposit which became less dense as the prism was moved away from the periphery and gradually faded away through yellow. The prism is shown in Plate II. The drawing was made immediately after the observation, but owing to the condition of the patient it could not be actually drawn from the eye, and is a memory drawing. The lower part of the prism is too curved, but the figure shows substantially the actual appearance. The child died shortly after the examination,

Plate II.



John Bale, Sons & Danielsson, Ltd lith

The upper drawing represents the anterior aspect of the eye as seen with the loupe, and shows the delicate golden glow upon the lower portion of the iris.

The lower coloured drawing shows the Kayser-Fleischer ring as seen with the slit-lamp. The beam of the lamp in passing through the cornea illuminates a sinuous block of cornea generally called the corneal "prism," with a curve mainly convex but reversed at the limbus. The anterior or epithelial surface is to the left, and is normal. On the right is the posterior or endothelial surface, which shows a granular pigmentation, brown above (near the limbus) and gradually becoming yellow and fading away towards the centre of the cornea, being no longer perceptible just central to the line where the cornea is seen crossing the inner edge of the iris. The corneal nerves shown on the prism are normal in aspect and are not increased in number.

and a full account of the histology of the cornea is given in *Brain*, vol. xlix, part 1. The section of the cornea is shown in Fig. 39. The granules seen with the slit-lamp are actually nodules in Descemet's membrane.

FIG. 39.—A section showing the nodules in Descemet's membrane which form the brown pigment dots seen with the slit-lamp in the Kayser-Fleischer ring.

The Kayser-Fleischer ring is found in other conditions, especially in pseudosclerosis, but they all have this in common, the presence of cirrhosis of the liver. It is probable that a slit-lamp examination will enable the diagnosis of Kinnier Wilson's disease to be made earlier than would be possible without it, but we would emphasise the difficulty of the examination and the necessity for expert manipulation.

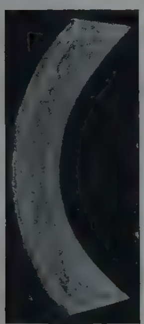


FIG. 40.—An optical section of the cornea in an early stage of conical cornea, showing that the thinning commences with an increased concavity of the posterior corneal surface, the curvature of the anterior surface at first remaining normal.

The Arcus senilis.—Although superficially the arcus senilis does not reach to the limbus, yet deeper in the cornea there is a continuous change right to the corneal periphery. This fact was discovered by Vogt.

Conical Cornea.—In the earlier cases of kerato-conus that we have examined the only change has been an increase in the concavity of the inner corneal surface without any appreciable alteration in the contour of the anterior surface. These have been cases in which retinoscopy has been impossible because of circular shadows, and yet examination with Placido's Rings has shown no irregularity. In the past such cases have been explained by invoking an irregular lental astigmatism. In a more advanced case we find an increased curvature of both surfaces with marked thinning of the apex. The first type of case is shown in Fig. 40. When a definite cone is formed the slit-lamp shows several characteristic changes. The endothelium is visible over an abnormally extensive area. This is a mere optical effect caused by the more acute curvature of the reflecting surface. We find a considerable increase in the number of corneal nerves, and in Descemet's

membrane folds and even actual ruptures. These are shown by several drawings in Vogt's Atlas and in Gallemaert's Monograph on the Cornea. Often there is a brown ring surrounding the base of the cone, *Fleischer's ring.*

Tumours of the Cornea and Limbus.—The slit-lamp enables us to observe the depth to which a tumour is penetrating into the corneal tissues. Employing the narrow beam, the conjunctival prism localises the different aspects of the growth, and so greatly helps in the diagnosis and treatment. We are able to watch the various outgrowths and to record their exact dimensions with the micrometer eyepiece. By this means we have an accurate means of judging whether the tumour is growing, both as regards superficial extent and depth. The importance of this knowledge need not be stressed, it is self-evident.

Plate III, Fig. E, is from a case of limbal tumour. The patient was demonstrated to the Ophthalmological Section of the Royal Society of Medicine, and was universally held to be a case of melanotic carcinoma. The tumour has been treated at the Radium Institute, and the result of irradiation is being carefully watched with the slit-lamp. Migration of pigment has been observed, and outgrowths which had an opaque, dirty-yellow aspect, and which were definitely raised above the corneal surface have been seen to shrink and become fibrosed. At present the tumour is in a retrogressive stage, and at the last examination had nearly vanished. Any increase in size or pigmentation will be obvious and can be met by adequate therapeutic measures. In this case no isolated deposits in the clear cornea have been seen.

An innocent limbal tumour is seen in Fig. 41. This was under the charge of Dr. Wheeler of Rugby. Part of the growth was sessile, part pedunculated. Examination with the slit-lamp showed that there were definite sprays of tumour growth, growing out superficially into the clear cornea, and this was held to be a sign of malignancy. Gallemaerts has figured a case of limbal sarcoma in which such sprays were present. A microscopic examination of the pedunculated portion showed that the tumour was of a nævoid type and innocent. It disappeared completely after two applications of radium.

Œdema of the Cornea.—Vogt calls this condition *Betauung*, or "bedewing." It is a most important phenomenon whose significance

will be discussed in the chapter on Inflammation. The appearance can best be described by comparing it to a looking-glass in a steaming bathroom. Seen under a magnification of 30 the affected area of the cornea appears to be covered with drops, hence the term "bedewing." The anterior or posterior surfaces may be implicated or both. If the condition is local we can discover by the usual methods of localisation whether it affects the epithelial or the endothelial surfaces, but when it is universal it is often difficult, sometimes impossible, to make the distinction. The best method is that of fine focus which has been described in Chapter II. Bedewing is

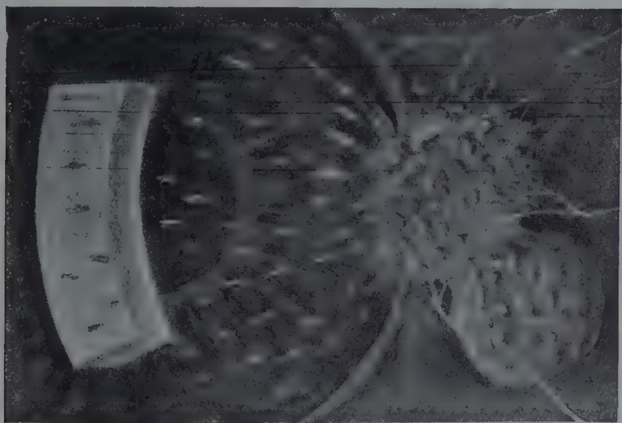


FIG. 41.—A nævoid growth at the limbus with a pedunculated outgrowth. Sprays radiate from the growth towards the centre of the cornea, and are demonstrated on the corneal prism to the left to be very superficial in the cornea.

physiological at the periphery of the cornea, and is frequently found in inflammation of the cornea or the uvea and in increased intraocular tension.

Lüssi's Line is seen in children. It is a vertical line extending from the lower limbus to a point corresponding to the lower margin of the cornea. The drop-like bodies are said to be cellular. The deposit is caused by the divergence of the descending aqueous current which flows to the right and left, leaving a central triangular dead area, a sort of back-water. The line varies with the position of the head, and with the warmth of the child. It may be seen when the patient comes indoors and may vanish when the corneal surface gets warmer in a hot room. The line is purely physiological.

Türck's Line.—This is a broader and longer line seen in the same position after a perforating injury to the cornea. The droplets are larger than in Lüssi's line.

Birth Injuries of the Cornea.—In many of these cases Descemet's

FIG. 42.—A birth injury of the cornea. Tears are seen in Descemet's membrane, and centrally a strip of the structure has separated and spans the anterior chamber as a chord.

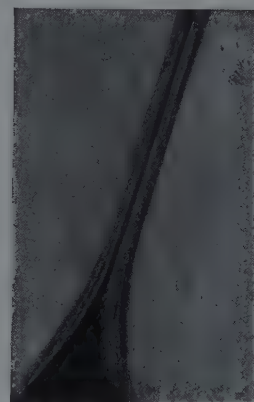


FIG. 43.—The strand of Descemet's membrane is seen magnified, and is found to be infolded like a spill.

membrane is torn and even detached. In the case illustrated in Fig. 42 there are several tears of this membrane, and a broad ribbon has become detached and folded into a spill-like strand which spans the cornea (Fig. 43). An area of desquamation was seen as a belt of opalescence across the cornea. Ballantyne showed slit-lamp drawings of similar cases at the Congress of the Ophthalmological Society in May 1926.

CHAPTER VI

THE ANTERIOR CHAMBER

WE have already seen that the slit-lamp enables us to measure the depth of the anterior chamber with reasonable accuracy. Taking advantage of the stereoscopic image, the depth can be judged by eye, and in ordinary clinical work this estimation by " eye " is generally sufficient. It is not common for the anterior chamber to be entirely abolished ; if this occurs the development of nuclear cataract is imminent. Although there may seem to be no chamber, in most cases the slit-lamp will reveal a space somewhere, often at the periphery, between the cornea and the iris. In many instances the pupillary crater is all that remains of the anterior chamber. Such a case is shown in Fig. 44. This eye had been trephined two years previously and the anterior chamber had not re-formed. The tension was normal and the visual acuity full. Six months later the anterior chamber disappeared and cataract formed.

FIG. 44.—The drawing shows abolition of the anterior chamber after a trephining operation. Only in the pupillary crater is there any evidence of a chamber. Eventually nuclear cataract formed.

The Aqueous " Flare " has been studied by Graves, who now calls this phenomenon *the outstanding beam*. We prefer the simpler term "*flare*." The normal aqueous is not optically inactive, and under suitable conditions the beam can always be perceived in the anterior chamber. The lamp must be giving a good light ; we run ours at 9 volts instead of 8, but the filament is robust and will tolerate 12 volts for some time. If we so adjust the beam in the anterior chamber that it occupies one-half of the pupil area we establish a contrast between the illuminated and the dark portions of the aqueous. Using a fairly narrow beam, we note a faint relucence along the path of light. This is due to the fact that the aqueous contains particles too small to be resolved by the magnification used. In practice it may

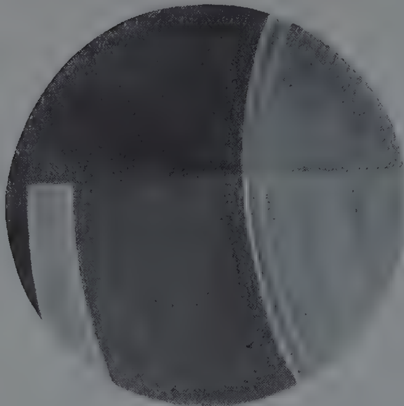


FIG. 45.—Demonstrates the method employed to show the flare in the normal aqueous. An exaggerated flare is shown in the Figure.

be taken as a measure of the protein content of the fluid. The method is illustrated in Fig. 45, which, however, shows a pathological flare. The physiological effect is too faint to be reproduced in a drawing. Another method recommended by Graves is to throw a pencil of light into the eye from the pin-hole diaphragm, and gently to oscillate it, viewing the region through which it passes by para-central vision. The flare will be obvious, and the stronger the light, the brighter the outstanding beam. The normal flare with the light-pencil is seen in Fig. 46, the pathological flare in Fig. 47, and the flare with particles in Fig. 48. The former method is more practical and the expert uses it constantly and automatically. It is most important to become thoroughly acquainted with the normal flare produced by the instrument used. Normal patients should be examined as a routine, for when once the normal flare is recognised the abnormal presents little difficulty.

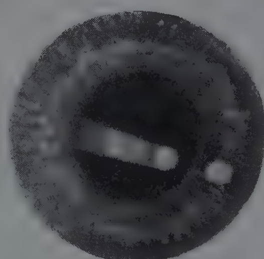


FIG. 46.—The normal appearance seen when a pencil of light is thrown into the eye. We note: the corneal cylinder; the dark anterior chamber; the lens cylinder, and the vitreous flare.

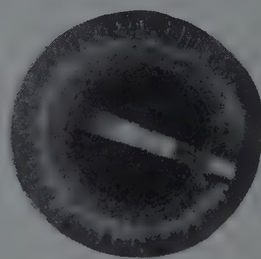


FIG. 47.—The same examination when the aqueous flare is pathologically intensified.

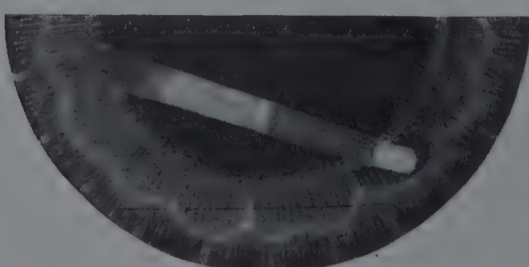


FIG. 48.—Demonstrates the presence of particles in the aqueous.

The Convection Currents in the Aqueous.—Whereas the corneal side of the anterior chamber is colder than the iris side, it is obvious that convection currents must be set up, and that their direction will vary with the position of the eye. When the aqueous contains visible particles they are seen to stream along with the

convection current. The particles are observed falling behind the cornea and rising on the iris side; in the centre of the anterior chamber they are at rest or move slowly in no regular direction. The heat of the slit-lamp causes various eddy currents and vortices. As we have already explained, the descending current tends to leave a dead triangle at the base of the cornea, and this fact probably explains the tendency for precipitates to deposit upon the back of the cornea in the form of a triangle with its apex at the vertex of the cornea. Fig. 49 demonstrates the presence of particles in the anterior chamber seen with the narrow beam. The eye had sustained a recent perforation and the aqueous was full of pigment granules. These have a red appearance.

FIG. 49.—The eye is illuminated with the narrow beam. The aqueous is full of granules which show convection currents.

It is not difficult for one who has attained reasonable skill in the manipulation of the slit-lamp to see particles in the aqueous when they are numerous, but it requires a trained observer to discover them when they are infrequent or consist of small white cells, or to say definitely that they are not present.[1]

The technique we have found most satisfactory is the following: The broad beam is chosen, and the lamp should be overrun. First define the corneal prism, and then the iris pattern. Focus a position midway between the two with lamp and microscope and observe intently. The room must be perfectly dark, and dark-adaptation is necessary. At first nothing is seen, then the beam becomes granular, and finally particles in motion become visible. It is helpful to know exactly where the focus lies and to imagine motion in the direction to be expected there. Thus if we are focused deeply in the chamber, the imagined motion will be upwards, close to the cornea it will be downwards. The granules gradually become clearer as dark-adaptation deepens. These particles can be seen with A 0,

[1] In a recent case of sympathetic ophthalmitis in which the anterior chamber was crowded with particles in active circulation we were able to see them clearly with the ordinary loupe and half-watt lamp, and the effect of the convection currents could be seen even more beautifully than with the slit-lamp because the whole anterior chamber was under observation at once. The best effect was obtained by observing the anterior chamber with the loupe under the illumination of the slit-lamp. Under these conditions the whole phenomenon could be seen with a condensing lens, and even with the naked eye an idea of movement could be gained.

a magnification of 15, but it is necessary to use A 3, an enlargement of 30, to make a careful study of the nature of the structures seen. Generally the observation is easier if the beam be so adjusted that the prism is just out of the field, and, if we have a dark background, the dilated pupil. Sometimes we see the particles best at the angle of the chamber where they can be doubly lighted, directly by the beam and indirectly by light reflected from the iris. This method is recommended by Vogt. If the objects are numerous the motion is easier to study by the narrow beam, because we obtain a greater contrast between the lighted particles and the dark background. The significance of these observations will be explained in the next chapter on Inflammation.

CHAPTER VII

INFLAMMATION

INFLAMMATION, especially uveitis, is probably from a practical point of view the most important subject in the whole range of ophthalmology, and it is here that the slit-lamp is of the highest value, in fact it is no exaggeration to say that it is not possible without this instrument to gain a complete grasp of ocular inflammation.

Corneal Œdema, which we have already described, is the earliest sign of irritation of the eye. There is some doubt as to the actual nature of endothelial bedewing. It has been suggested that it is due to the deposit of droplets upon the surface; whereas others see an actual modification of the endothelial cells. The distinction has little practical significance. There is no doubt that changes sometimes occur in the endothelial cells during inflammation, especially when the cornea is the seat of the change. They tend to lose their outline, and frequently become invisible. Instead of cells we see a granular appearance with craters only. As the inflammation subsides the cells assume their normal characteristics.

Bedewing is not confined to inflammation. It is seen under other conditions which have already received notice. As a sign of inflammation bedewing is too delicate to be of great value. Thus we have seen it after a cataract operation, not only in the eye operated upon, but in its fellow; this effect may be caused by the double bandage. On the other hand, marked bedewing whether of the epithelial or endothelial surfaces in the second eye should awake suspicion, for it may be the first sign of a sympathetic ophthalmitis. For this reason it is essential, before any operation upon the globe, to make a careful examination of both eyes with the slit-lamp and note any bedewing or increased flare. On one occasion we had the choice of either eye for extraction. The right eye showed some bedewing and the left was selected. The operation was followed by considerable irido-cyclitis, so much so that the question of excision

was considered. Had we not known that the slight inflammatory signs in the right eye were present before operation, their detection would have turned the balance in favour of enucleation: in the event the eye made a slow but complete recovery.

Increased Aqueous Flare.—This sign again is a very delicate indication and must be used with due appreciation of its limitations. The remarks we have made about the value of bedewing apply with equal force to increased flare. A well-marked relucence denoting an aqueous heavily charged with proteins is a sign of inflammation, and to some extent an indication of its severity. Relucence appearing in the other eye after an operation should never be disregarded, but here again full consideration must be given to the extreme delicacy of the reaction. It is again possible that bandaging the eye may be responsible. It is quite certain that both bedewing and increased flare may appear to a well-marked extent in the fellow eye after operation, and completely disappear without any permanent damage remaining; on the other hand, it may be the first warning of a sympathetic ophthalmitis, one that cannot be acted upon till we get a further indication, the appearance of cells.

The Presence of Cells in the Aqueous.—This is by far the most important sign of uveal inflammation. The ability to discover cells in the anterior chamber, the retro-lental space, and the vitreous is the most valuable feature of the microscopy of the living eye, because IT ALLOWS US TO RECOGNISE SYMPATHETIC OPHTHALMITIS SEVERAL DAYS IN ADVANCE OF THE APPEARANCE OF MORE OBVIOUS SIGNS. Vogt says that if the slit-lamp had no other value than the ability to recognise sympathetic ophthalmitis at an early date, it would justify its cost and the trouble necessary to master its technique, and we feel that all who have saved an eye by the indications of the slit-lamp will fully agree with him.

We shall see reason to think that the anterior and posterior chambers, the peri- and retro-lental spaces, and the vitreous, are in reality but one chamber filled with aqueous. The lens is wholly surrounded by aqueous; there is free communication round the lens—free to fluid, free to cells, and even to large tumour masses. There is no suspensory ligament in the old sense, no diaphragm. It is practically certain that the vitreous fluid is in free communication with the retro-lental space. The slit-lamp affords no support to the existence of a hyaloid membrane—in fact, Koeppe has shown

that if the eye be examined with polarised light, we see a play of colour in the region of Bowman's membrane, and of Descemet's membrane, but no suggestion of the same effect on the face of the vitreous. He insists that this observation excludes anything in the nature of a vitrified membrane, and suggests that the hyaloid membrane is in reality a fine network. The first vitreous "impact line," which might be taken to represent the hyaloid, waves like a film of gossamer with all and every movement of the eye. There can be no membrane like the skin of a child's balloon.

Particles in the Retro-lental Space are generally easier to see than those in the anterior chamber. We approach the illuminating to the visual axis, use a moderately narrow beam, and obtain a sharp focus upon the posterior capsule. Behind the capsule we see a dark zone in front of the first impact line of the vitreous, the retro-lental space, and here we discover the floating particles. Generally they are plentiful in the retro-lental space. They are also seen infiltrating the vitreous, an indication of the physical continuity of the two regions. In most cases of inflammation the cells appear first in the vitreous and retro-lental space, and after some time are present in the anterior chamber. The commonest cause of massive outpouring of cells into the vitreous is choroiditis of the exudative type. When, in the absence of marked signs of inflammation, the aqueous contains numerous cells, choroiditis is usually present.

Although particles in the aqueous are normally in active movement, this is not the case in acute inflammation. When the albuminous content of the fluid reaches a certain concentration they come to rest, and renewed activity is the first sign of a diminution in the inflammatory process.

Blood-Cells are found in the aqueous after contusions, wounds, and operations, and when numerous, form a hyphæma in the anterior chamber or the retro-lental space. There is a difference of opinion as to their colour, but to us they appear a yellowish hue.

Pigment Granules look brown or red. After any wound of the iris pigment granules escape and float in the anterior chamber. Eventually they disappear, but in the aged they tend to be deposited upon the iris, the anterior capsule, and sometimes upon the endothelial surface of the cornea.

It is very doubtful if particles, whether cellular or otherwise, can adhere to a normal endothelial surface. We have seen

that in certain inflammatory conditions these cells show changes which can be recognised with the slit-lamp, and the opinion of those who hold that the presence of precipitates postulates a modification of these cells is probably correct. It is quite common to find the anterior chamber choked with cells without any trace of K.P.

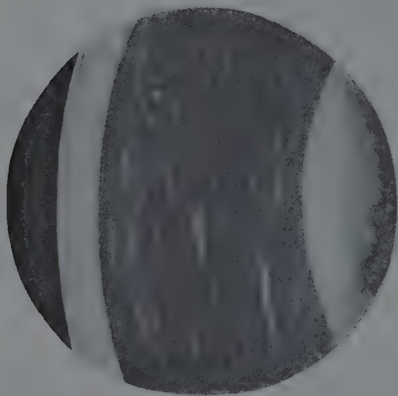


FIG. 50.—Large flocculi of lens substance floating in the aqueous and causing glaucoma by blocking the iridic angle.

We once saw a patient ten minutes after a wound of the iris: the aqueous was full of brown pigment cells in active circulation and some were present a week later. In a normal eye we recently saw a large clump of pigment floating freely in the anterior chamber. Hill Griffiths and others have observed tumour masses in the aqueous. The pigment in a case of iritis is derived from the pupil margin. The folds of the retinal layer which form the pigmented margin are seen to be wasting and in some cases disappear. Some of the pigment is deposited upon the anterior capsule, but occasionally granules are detached and swim in the aqueous.

Lens Flocculi are found in the aqueous after wounds and contusions, and are the cause of the glaucoma associated with this class of case. They are seen in Fig. 50, an example of glaucoma due to lens injury.

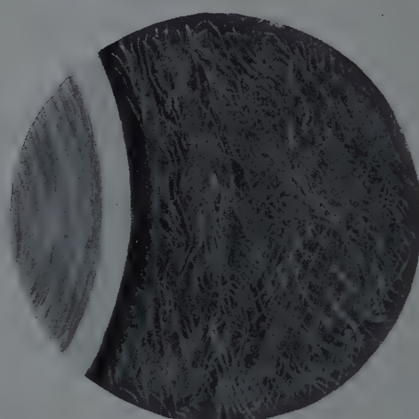


FIG. 51.—An atypical but normal vitreous. The retro-lental space is well shown, but is not sharply demarcated from the vitreous. There is no evidence of any hyaloid membrane.

CELLS IN THE AQUEOUS

In cyclitis, and essentially in choroiditis, we find cells in the aqueous, the retro-lental space, and infiltrating the vitreous. Their advent is so important that they merit careful study. Fig. 51 shows the appearance of the normal retro-lental space. The vitreous is atypical, but not pathological. Instead of the usual membranes the

vitreous chamber is filled with filaments like cotton waste. Although in this case we can sharply differentiate the retro-lental space from the vitreous, there is no impact line and no suggestion of a hyaloid membrane. Fig. 52 was drawn from a case of " hyalitis " under the care of Mr. Alabaster, which ultimately developed into pan-ophthalmitis. The back of the lens is furred with trails of exudate which wave in the retro-lental space. The vitreous is infiltrated with cells which have a yellow hue. The word " cells " may signify clumps of cells, but whereas Vogt thinks that we can see the actual blood cells in the capillaries, it may well be that the particles that we see are in effect discrete cells. It by no means follows that the living cell has dimensions identical with those hardened and observed under the microscope. My own view is that the particles are separate cells. Fig. 53 is a most instructive case. A solitary " tubercle " was present in the choroid. Whether these masses are tuberculous or not need not concern us. The retro-lental space is normal. When the eye is at rest the vitreous face presents the usual marbled appearance. There are no folds on its surface. The first vitreous membrane gives the bright impact line that we are accustomed to see, the line that suggests a hyaloid membrane, but when the eye moves the membrane is thrown into the folds shown in the drawing. It is attached above and at once returns to its original place. On this anterior fold a collection of yellowish nodules are seen, perhaps tubercles, and the vitreous is full of cells. A few days later disorganisation of the vitreous commenced, the normal architecture vanished and was replaced by fluffy clouds and cellular infiltration. The fundus was now invisible, cells appeared in the aqueous, and there were pellucid precipitates upon the endothelial surface. This case illustrates the facility with

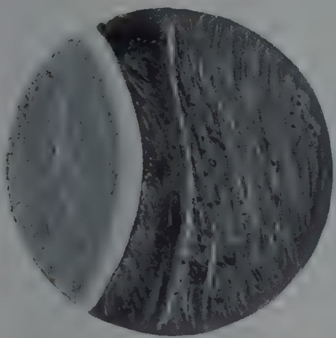


FIG. 52.—A case of " hyalitis."

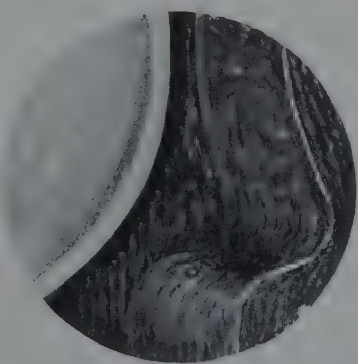


FIG. 53.—" Tubercles " on a vitreous membrane.

which all the stages of a severe uveitis can be studied with the slit-lamp.

Keratic Precipitates ("K.P.")

Corneal precipitates are best examined with both direct focal and retro-illumination, and with an alternation of both methods. The view obtained by transmitted light is quite different from that seen under direct focal light, and much information is gained by using first one and then the other. To study the minuter details the higher magnifications are useful, and it is here alone that we have found any advantage from the ocular 4 which with objective A 3 gives a magnification of 60.

Drop-like Precipitates.—Occasionally K.P. takes the form of small deposits exactly like drops of water. This type does not seem to indicate a dangerous inflammation.

Pigment Granules.—After injuries to the iris and in some forms of iritis a deposit of pigment granules is seen on the posterior surface of the cornea. They are apt to be more numerous in the case of brown irides. These pigmented precipitates are not important, and after injury have no significance. K.P. is not common in pure iritis, and when present is of this pigmented type. The presence of pigmented K.P. after an operation upon the globe should not cause alarm, and the darker the pigment the more innocuous it is.

Flakes of Cortex.—After an operation upon the lens it is not uncommon to find flakes of cortex adhering to the back of the cornea. This is not a sign of inflammation. They can be recognised by their wholly irregular shape and by the character of the material.

Opaque White Precipitates.—This form of K.P. is of more serious import than those we have mentioned. The foci are sharply circumscribed, circular in outline, and are dense and opaque. They are sometimes speckled with yellow dots, and indicate a mild cyclitis and perhaps a choroiditis. They are in no wise of such evil import as the next type.

Pellucid Precipitates.—These deposits are finely granular in texture, opalescent, and not sharply demarcated. The edge is delicately crenellated and may trail off into a smear of pasty material. The lower part of the cornea is often plastered with a layer of the same substance. This form is the most ominous, and is seen in severe inflammation of the uvea: in exudative choroiditis, syphilitic inflammation,

tuberculous uveitis, and most important of all, sympathetic ophthalmitis.

Koeppe has classified the forms of K.P. He places tuberculous uveitis and sympathetic ophthalmitis in the same category. His

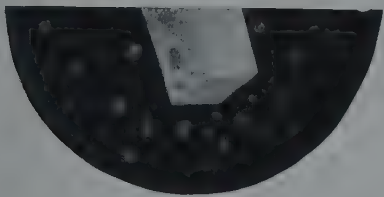


Fig. 54.—Opaque white "K.P." Small, sharply defined circular deposits.

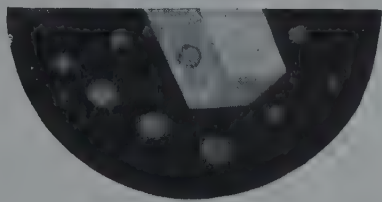


Fig. 55.—Large white "K.P." The white deposits are speckled with yellow granules.

observations in this respect have not received sufficient recognition; as far as we are able to judge they can be fully confirmed by careful observation of K.P. under high magnification, with No. 4 ocular and A 3 objective, an enlargement of 60 diameters; and we feel convinced that a full knowledge of the character of corneal precipitates will prove a stepping-stone to an accurate diagnosis in many doubtful cases. We shall return to the subject later. An attempt has been made to exhibit the differences between the various types of K.P., but the subject requires a trained artist.

Fig. 54 shows K.P. of *the solid type* following a blow upon the eye. Fig. 55 *the larger opaque form* speckled with yellow dots. This was taken from a case of choroiditis juxta-papillaris and disseminated choroiditis with a negative Wassermann reaction. *The pellucid type* is seen in Fig. 56.

Fig. 56.—The pellucid type of "K.P."

Nodular Deposits upon the Iris.—In cases of severe cyclitis and of active exudative choroiditis small translucent nodules are not infrequently seen upon the margin of the pupil, and less commonly upon the surface of the iris. The first time we saw them with the slit-lamp we thought they were small tubercles, but it was noted that a nodule disappeared in a day or two and a new one formed in

another spot. Friedenwald has studied these deposits and ascribes them to exudative choroiditis. The nodules have a transparent texture like the pellucid K.P. and suggest the same origin and nature. They may be regarded as massive K.P. on the iris. We have noted them in that quiet but intractable type of iridocyclitis which is so common in women, and which is in all probability due to septic infection from the generative organs. They are not vascularised and are ephemeral, often disappearing in the course of a day. Perhaps the " tubercles " described by Marple as occurring in the choroid in cases of tuberculous meningitis are of the same type. He stated at an Oxford Congress that in cases of tuberculous meningitis " choroidal tubercles " were constantly present, but that they were so evanescent that they were overlooked unless the examinations were frequent. It is difficult to imagine that real miliary tubercles could be seen in the evening and vanish next morning. Probably his observations refer to deposits upon the surface of the retina of the same nature as the iris nodules under consideration. The exudative nodes rapidly absorb and re-form in a neighbouring situation. It has been stated that these nodules can develop into synechiæ. In a recent case of sympathetic ophthalmitis we have watched this process take place, but in general the nodules absorb and disappear.

Threads and Coagula in the Anterior Chamber.—These are not associated with cyclitis or choroiditis, but with a gonococcal iritis. Devereux Marshall taught that the presence of a coagulum in the anterior chamber was pathognomonic of a gonococcal infection. This may be somewhat dogmatic, but we can say that every patient in whom we have found this condition has been suffering from gonococcal iritis, and we are personally in entire agreement with Devereux Marshall. We have recently had the opportunity of studying a case of this nature. Some eight years ago we were consulted by a man who was suffering from gonorrhœa and had a severe iritis. He now appears again with an acute recurrence. The anterior chamber was seen with the slit-lamp to be half-full of a clear coagulum which contained visible solid particles. There were no cells free in the aqueous and no K.P. Under treatment the coagulum absorbed and the aqueous became clear. Four days later the eye relapsed, and again the anterior chamber contained a massive transparent coagulum. There was no K.P. and no free cells. This severe recrudescence was associated with acute articular rheumatism, and the

patient was confined to bed for a fortnight. We did not see him again for a month. The iritis was now much better and the aqueous clear, but for the first time a little fine pigmented K.P. was detected. This case not only illustrates the rapidity with which coagula may form and absorb, but also confirms the view that K.P. is generally absent even in very acute iritis. In the later stages the ciliary body participates and K.P. may be found, an indication not of iritis, but of cyclitis. When K.P. is associated with uncomplicated iritis it is of the small pigmented type.

Fibrin threads are not infrequently seen in the anterior chamber in an iritis of the toxic type, the so-called " rheumatic " iritis. It is quite probable that this formation is also indicative of a gonococcal origin.

Hyperæmia of the Iris Vessels can be examined in great detail with the slit-lamp. Although the whole substance of the mesoblastic iris is composed of blood vessels with a little loose connective tissue, yet even in the most acute iritis, only a few of them are seen to contain blood, and it would appear that the majority are functionless. In iritis the vessels of the circulus minor are obvious. They are seen to be vascular arcades, for, as is well known to anatomists, there is no circle in the strict sense.

Sympathetic Ophthalmitis

It is impossible to overestimate the importance of a slit-lamp examination, of repeated examinations, in cases in which there is the slightest suspicion of this formidable complication. Often the diagnosis depends absolutely upon the result of these investigations, and they must never be omitted. The verdict of the slit-lamp compels us to remove eyes which appear harmless and enables us to retain those that are apparently dangerous. We estimate that during the three years that we have used the slit-lamp we have saved six eyes that would have been lost had we depended upon the older methods of examination. The slit-lamp affords the following information :

The presumptive exciting eye is probably not suffering from sympathetic disease, and the other eye shows no signs of sympathetic inflammation.

The presumptive exciting eye is showing definite signs suggesting sympathetic disease, and the second eye so far is free from such signs.

The uninjured eye is showing definite signs of sympathy.

That a bilateral irido-cyclitis associated with an injury to one eye is almost certainly not sympathetic in nature.

Apart from the knowledge gained from the slit-lamp the ordinary signs may not be sufficiently definite to make the diagnosis reasonably certain, and eyes are removed to " be on the safe side."

Schirmer lays down the following criteria of sympathetic ophthalmitis :

There must be a uveal inflammation in the exciting eye.

The time interval between the inflammation of both eyes must be at least fifteen days, but may be much longer.

The sympathising eye must suffer from uveal inflammation.

Careful examination of the whole body must fail to discover any other cause for the inflammation.

He states that the diagnosis cannot be made with absolute certainty, since identical symptoms may be due to varied causes.

The slit-lamp gives us further information which greatly reduces the number of doubtful cases.

The characteristic sign of a sympathetic inflammation, a sign which it shares with allied conditions such as tuberculous cyclitis, severe cyclitis in general, and with exudative choroiditis, is the presence of cells in the vitreous, the retro-lental space, and the anterior chamber; in a word, cells in the aqueous. Later signs are pellucid K.P. and exudative nodules on the iris.

If in the case of an injured eye, which is under suspicion of being a possible exciting eye, we examine the aqueous and fail to find cells in the anterior chamber, in the retro-lental space, or in the vitreous, then it is very improbable that the eye is dangerous from the sympathetic standpoint. At the present time there is not sufficient evidence to make the statement more positive.

If, on the other hand, in addition to the ordinary clinical signs we find an infiltration of the vitreous with cells, with or without cells in the retro-lental space, and the anterior chamber, then the presumption that the eye is dangerous is very greatly strengthened.

Finally, if cells are found in the same situations in the fellow eye, with or without more obvious signs such as K.P., and ciliary injection, then the eye is sympathising, and active treatment must be initiated at once, even if the signs of inflammation are slight.

The following is an example to illustrate this last point : A child aged eight was admitted to the Birmingham Eye Hospital. She

was a pale, feeble-looking girl, just the type that is said to be especially liable to sympathetic ophthalmitis. Fourteen days previously she sustained a small puncture in the limbal region. There was an iris prolapse which was as far as possible abscised by the house-surgeon. The eye was perfectly free from inflammation, the media were clear, and the acuity 6/6. The question that it might possibly be a dangerous eye was not considered. Fourteen days after admission a little K.P. was noted with faint ciliary blush. Examination with the slit-lamp revealed the fact that the anterior chamber was full of cells which were perfectly stationary. There was an increased flare and the vitreous was infiltrated on both sides. The acuity of both eyes was normal. In the exciting eye fine vitreous opacities could be seen with a + 20 lens behind the ophthalmoscope. An injection of neo-kharsivan was given, *and next day the cells were in active motion.* This was a most interesting fact, showing graphically the beneficial action of the arsenic preparation. On the next day exudative nodules were seen on the iris margin of the exciter, which was now excised although it had full 6/6 acuity. The eye was sent to Mr. Treacher Collins, who kindly examined it, and reported that it exhibited the typical Fuchs' type of inflammation, and was undoubtedly a highly dangerous eye. The cells gradually disappeared from the sympathising eye, which apparently made a complete recovery. Occasional cells were found for some months, and eventually no trace could be found. The child was watched for nine months, and cells were seen for eight months. At a later date the cells reappeared, a year after the accident, and it is obvious that the eye is even now not out of danger. A fresh course of neo-kharsivan has been initiated.[1] At no time did this eye manifest any of the ordinary clinical signs of inflammation, with the sole exception that occasionally one or two fine spots of pellucid K.P. were noted. After the excision of the exciter the cells in the sympathising eye again became immobile and for the second time an injection of kharsivan induced movement. The child received two complete courses of these injections.

There is in our mind not the remotest doubt that had the patient not been examined with the slit-lamp the excision of the eye would have been delayed till it was too late.

A case of double iritis appearing six months after an iridencleisis caused considerable anxiety till the slit-lamp examination showed

[1] When last seen the eye was free from any abnormal signs.

that there was no infiltration with cells, and that the K.P. was wholly pigmented. This patient made a complete recovery, and it appeared that the iritis had nothing to do with the operation.

The mere presence of bedewing and increased flare in the possibly sympathising eye is not sufficient ground for removing a doubtful eye. We had a case of this kind, and both eyes recovered with perfect acuity.

In yet another case after a cataract operation the eye showed K.P., and was injected for a long time and then recovered. It relapsed again, and, in spite of the fact that there were no cells in the anterior chamber or the vitreous, it was excised. Examination showed that there was not the typical Fuchs' type of inflammation.

CHAPTER VIII

THE IRIS

MOST of the early work upon the slit-lamp has been done in German-speaking countries, and we have to translate the terms they employ, many of them new ones, into suitable English equivalents. Unfortunately in some cases the rendering has been too literal, with the result that we find such words in use as " the narrow bundle," meaning the narrow beam. In the case of the iris we have to select new expressions for the various parts which have so far not received adequate names.

The iris consists of four layers : the internal retinal pigmented layer, the radial muscle layer, the posterior and the anterior mesoblastic plates.

The Anterior Leaf of the Iris, starting from the periphery, generally ends at a spot about a third of the way from the periphery, in a slight eminence where we find the circulus minor. The French call this the "*collerette*." This term is better avoided, because it has been used by Gallemaerts to indicate the pupil margin. The English word "*frill*" seems suitable and we have adopted it. Generally the connections between the anterior and posterior mesoblastic leaves are not intimate, with the result that the two layers move freely over each other, much as the skin of a rabbit slides upon its body. In consequence the outer layer does not to any marked extent participate in the movements of the iris. It follows that when the pupil is dilated the sphincter lies close to the frill, but when the pupil contracts it leaves the frill behind it. It is also due to immobility of the anterior leaf that fine telegraph-like filaments of the pupillary membrane, stretching from frill to frill across the pupil, are not torn away when the pupil dilates, and do not always sag when it contracts. We find spaces under the anterior leaf, the clefts of Fuchs, which are easily seen with the slit-lamp. It is common to find large defects in the anterior layer through which the middle layer is visible. It has a darker colour than the anterior, because the absence of a layer allows the

pigment in the retinal layer to be more evident. These clefts are also by some called Fuchs' clefts. A case has been recorded in which the outer leaf had become detached and lay free in the anterior chamber.

In another type of iris the two layers are closely interwoven and the frill is absent or rudimentary.

There can be little doubt that the development of the outer leaf is associated with the history of the pupillary membrane. Vestiges of this structure are invariably attached to the frill and to no other part of the iris.

Occasionally in inflammation of the iris we may see some of the vessels of the *circulus minor.* It is not a true circle, but merely a series of arcades, the remains of the primitive vascular loops of the iris. The small circle rapidly disappears in atrophy of the superficial layer, and probably its function is restricted to the nourishment of this structure.

The Contraction Rings are beautifully seen with Czapski's microscope, and we may observe how they smooth out when the pupil contracts.

The Sphincter Iridis is clearly visible in a blue iris and in darker irides which have become atrophic, and is best studied by indirect lateral illumination. It forms a brown zone round the pupil of an atrophic iris. Occasionally we find a brown amorphous-looking iris which when magnified resembles a rubber bath sponge. Such an iris has no frill.

The Pupil Ruff.—The pupil margin is encircled by a pigmented chain of nodular bodies which Gallemaerts calls the "mamelons." For the want of a better word we shall employ this term. These prominences are the everted edges of the folds of the posterior surface of the iris. The mamelons above the pupil are always larger than those on the lower segment. In the horse large clumps of pigment hang down from the upper margin of the ruff, and such are occasionally seen in man. A double row of mamelons is sometimes present. In the young the ruff, if present, is always perfect, but in the aged many of the mamelons are absorbed and gaps are seen in the ruff. In iritis the mamelons are often seen with the slit-lamp to be in a state of disintegration, and the pigment collects in small heaps upon the anterior capsule, or may float freely in the aqueous, to be deposited upon the surface of the iris and of the cornea.

Occasionally in diabetes a characteristic change takes place in the mamelons, which appear swollen and œdematous. There is no doubt that this appearance, which is quite typical, is but an obvious sign of a degeneration of the posterior pigment layer of the iris. The change is so definite that we have on several occasions diagnosed diabetes from mere inspection of the iris with the slit-lamp, and on examining the urine have found sugar. On the other hand, it is absent in many diabetic patients.

Abnormalities and Disease of the Iris.—Atrophy of the iris in all its varied forms can be fully investigated during life only with the

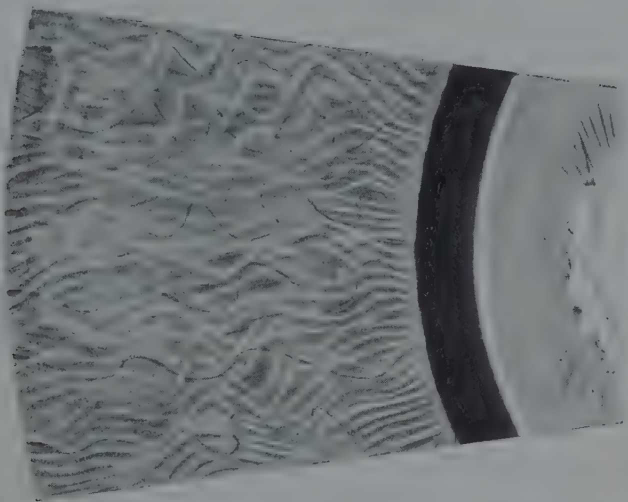


FIG. 57.—Advanced atrophy of the iris. To the right a shrunken lens with herniating cortex. Centrally the iris sphincter, but no ruff. To the left highly sclerosed vessels with a few tortuous functional arteries.

slit-lamp. Senile atrophy affects the pupil ruff and the regions of the sphincter. The mamelons tend to become fewer and may completely disappear, leaving a translucent zone round the pupil which is almost transparent when examined in lens light. More advanced atrophy affecting the whole structure of the iris is seen after long-continued chronic irido-cyclitis and in hetero-chromic cyclitis. There is a chronic form of iritis affecting the retinal layer, and apparently devoid of symptoms, which can be detected only by the moth-eaten appearance of the iris when examined in lens light.

An example of advanced atrophy caused by long-continued irido-cyclitis, the sequel to a perforating injury of the globe, is shown in

Fig. 57. The lens is cataractous, and the cortex is herniating through a rupture. The anterior layer, with the frill and the circulus minor, has entirely disappeared. The middle layer is highly atrophic, the contraction rings have smoothed out, and the brown sphincter is plainly visible. The remaining mesoblastic tissue shows the structure of the iris very plainly. The anterior layers of the normal iris are composed almost entirely of blood vessels joined by a little loose connective tissue. The arteries have an enormously thick adventitia. Probably the majority are functionless and cannot carry

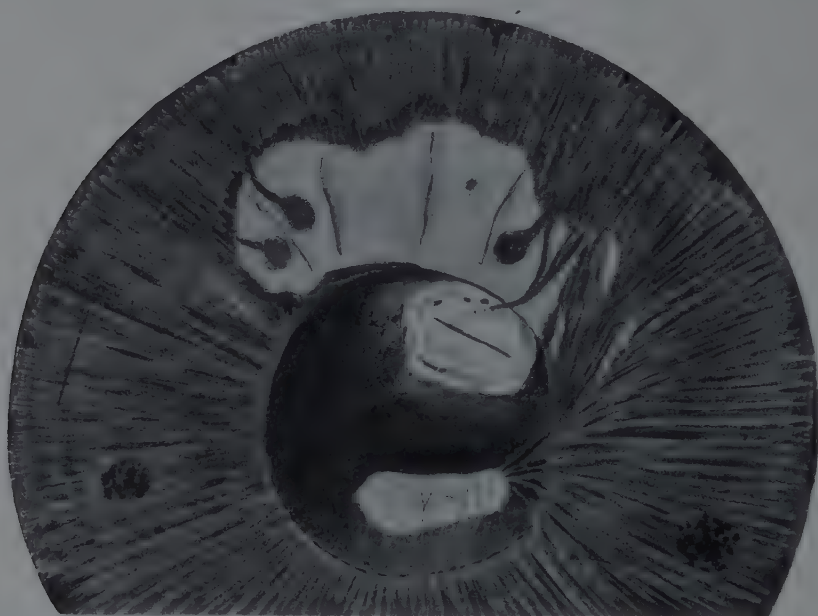


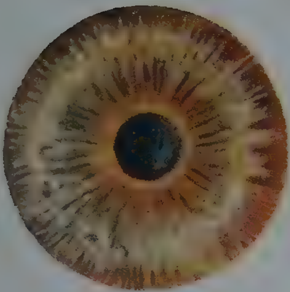
Fig. 58.—An atrophic iris. The mesoblastic layers are ragged and "moth-eaten." The retinal layer is bleached,[1] and has a wash-leather appearance. There is an anterior polar cataract and an adherent leucoma.

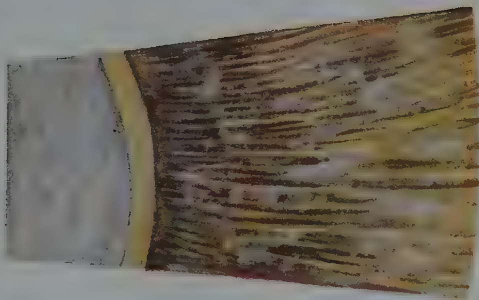
blood. Here and there in an acute inflammation some of them are seen with the slit-lamp to contain a column of blood. In the drawing the vessels composing the tissue are clearly shown as white lines; they are in a state of advanced sclerosis, and are few in number. Some of them are active blood vessels. The pupil ruff has disappeared entirely.

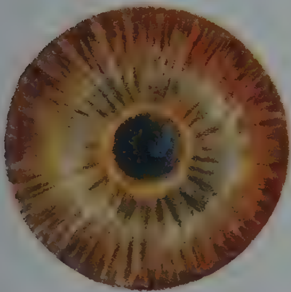
The changes that take place in hetero-chromic cyclitis are illustrated in Plate III. In Fig. A a very early stage in the disease is seen. Here the anterior mesoblastic layer is the only part affected. If the drawing be compared with Fig. B, the fellow normal eye, it

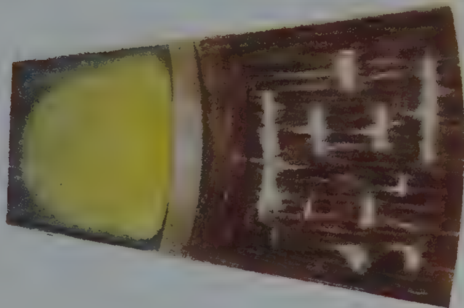
[1] Miss Ida C. Mann suggests that the retinal layer is not bleached but is covered by fibrous tissue as in a case examined by her microscopically.

PLATE III

A 

 D

B 

 C

E

A.—An early case of hetero-chromic cyclitis. The anterior mesoblastic layer is atrophic and has a white sheen. B.—The fellow normal iris. C.—A case of hetero-chromic cyclitis. The iris is illuminated by lens light and shows numerous apertures in the iridic layer. D.—The same iris in focal light showing atrophy of the meso-blastic layers. E.—A melanotic carcinoma of the limbus. The drawing shows the sprays of tumour growth spreading superficially in the cornea.

will be noted that this structure is thin and transparent with a white sheen.

A far more advanced case with cataract and K.P. is shown in Fig. C. The iris is illuminated with lens light, which is strongly reflected from the cataractous lens. The defects in the retinal layer are manifested by their transparence, and the general eroded appearance of this layer is obvious. Fig. D represents the same iris lighted by direct focal illumination. This method demonstrates the atrophy of the mesoblastic portion of the iris.

A somewhat extraordinary example of iris atrophy is seen in Fig. 58. The whole of the mesoblastic iris is absent over wide areas. The pigmented layer below is totally bleached and has a wash-leather appearance. There is an adherent leucoma and an eccentrically-placed anterior polar cataract. Probably the inflammation was intra-uterine and gonococcal: there has been a perforation of the cornea to which the iris has adhered and the lens has come into contact with the cornea.

CHAPTER IX

THE PUPILLARY MEMBRANE AND THE SUSPENSION OF THE LENS

The Tunica Vasculosa Lentis Anterior

THE slit-lamp shows that vestiges of the pupillary membrane are very frequent, in fact traces of this structure can be discovered in about one eye in ten.

The commonest form is a collection of brown dots on the anterior capsule generally near the centre. Their appearance when examined

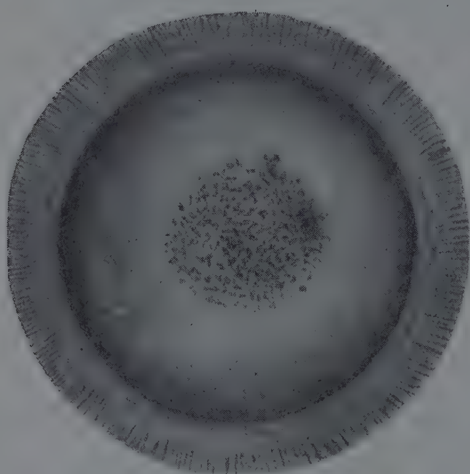


Fig. 59.—A collection of embryonic "stars" on the anterior capsule, and white-of-egg opacities in the capsule.

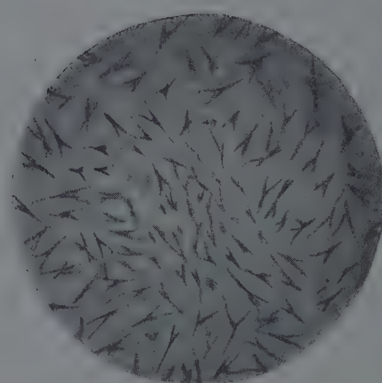


Fig. 60.—The "stars" highly magnified.

with the loupe is shown in Plate IV, Fig. A. Fig. B shows them under a magnification of 35. The dots are seen to be stellate and generally tripolar. Their arms often end in a grey filament which may anastomose with the arm of a neighbouring star. Sometimes they form a fine grey network upon the surface of the capsule, and this may be sufficiently dense to reduce the visual acuity. Ernest Thomson has drawn attention to this type, which is now and again discovered in the routine examination of children. These vestiges may be

accompanied by opacities in the capsule which have the colour and texture of white of egg. This type is shown in Figs. 59 and 60.

All pigment deposit upon the anterior capsule tends with lapse of time to assume the stellate form. In an old case of interstitial keratitis or of chronic iritis one may find clusters of stars and even the grey filaments with a deposit of a white, silky, cocoon-like material. It may be impossible to decide whether the stars are congenital or inflammatory. Generally speaking the inflammatory stars are not so symmetrical as the congenital and they do not as a rule form the regular meshwork that characterises the congenital deposit. It is wise to make a study of the deposits of pigment in cases of past iritis, and to compare the configuration of the pigment with that in a case of congenital stars.

We have seen a star formation within a year of the deposit of inflammatory pigment.

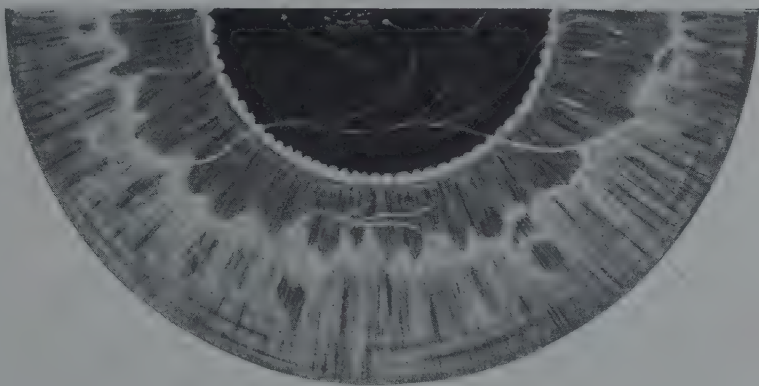


FIG. 61.—Vestiges of the pupillary membrane. Filaments arising from the "frill" and crossing the anterior chamber. Some branches float free and end in knobs.

Another common form is seen in Fig. 61. Fine filaments arise from the iris frill and branch out freely into the anterior chamber. In this example each ended in a knob. Sometimes similar strands stretch right across the anterior chamber from frill to frill like telegraph wires. Filaments may end in tufts of cotton-like material, and may be wholly confined to the iris. Bedell has published some beautiful drawings of these vestiges. They are very common and are constantly seen in routine slit-lamp work. Instead of fine threads thick strands may persist. These are the remains of the larger vessels of the pupillary membrane. They are commonly associated with an anterior polar or capsular cataract. An example is drawn in Fig. 62. Here thick cord-like bands leave the frill and are attached to the anterior capsule in the centre, where there is a capsular opacity. A similar condition is seen in Fig. 63. Other

drawings will be found later on when we are discussing anterior polar cataracts. There can be little doubt that these extreme examples

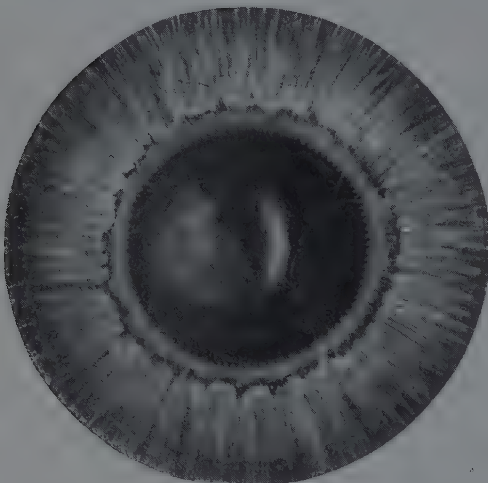


FIG. 62.—Telegraph-line vestiges of the pupillary membrane with anterior capsular opacities.

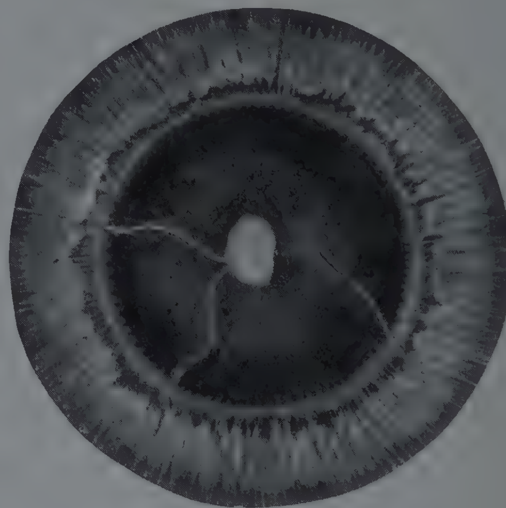


FIG. 63.—Remains of some of the larger vessels of the pupillary membrane with an anterior polar cataract.

are due to an intra-uterine inflammation that inhibits the normal retrogression of the tunica vasculosa.

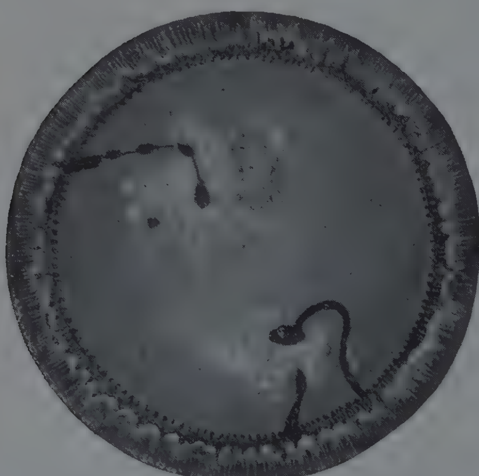


FIG. 64.—A case of intra-uterine iritis contrasting with the true vestiges of the pupillary membrane.

Occasionally we see a case that at first sight is one of the type we are considering. At the pupil edge there are thick synechiæ which appear to be folded. When the pupil is dilated this fold disappears and a broad, band-like adhesion becomes visible. Generally the synechia ends on the anterior capsule in a paw-like expansion. It is usual to find a crop of stars and sometimes a deposit of white material like the silk of a cocoon. Whereas the adhesion starts from the ruff and not from the frill it is obvious that it is not a vestige of the tunica vasculosa. These cases are examples of intra-uterine iritis. A case of this kind is portrayed in Fig. 64.[1]

[1] In Dec. 1926 Mr. Beatson Hird showed to the Midland Ophthalmological Society a case of glaucoma in a child. Examination with the slit-lamp revealed a picture identical with Fig. 64.

The Suspension of the Lens

The lens is suspended in the eye by the zonular ligament as a hub is maintained in position by the spokes. It is completely surrounded by the aqueous and is not normally in contact with the vitreous architecture. If this arrangement is disturbed and the lens comes into contact with the cornea or the vitreous, there is a tendency for its nutrition to suffer, and for nuclear cataract and posterior opacities to develop.

The suspension of the lens is strikingly illustrated by Fig. 65, taken from a very rare condition found in a buphthalmic child at Sunshine House, Leamington, a home for blind babies. The examination was made under great difficulties, and the drawing was made from memory. We have seen the child again, and find that the lens has been drawn somewhat too small, it should be 25 per cent. larger. The iris was reduced to a mere ring and was imperfectly developed. In the centre of the eye a globular lens is suspended by a zonular ligament which under adequate focal illumination can be seen with the naked eye, giving the impression of a glistening membrane with a shot-silk sheen. The loupe resolved this into filaments. Examined with the slit-lamp the zonule appeared to be normal, except that the fibres were abnormally long and were not grouped into strands. They were present in immense numbers, far more than are shown in the drawing.

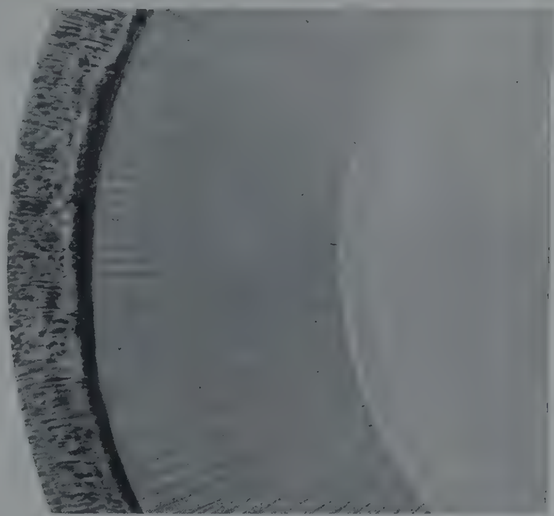


Fig. 65.—A case of buphthalmos with a lens in a condition of arrested development, showing the fibres of the suspensory ligament.

The fibres are attached to the anterior surface of the lens well away from the equator, and others are seen passing backwards to form a similar attachment behind the lens. The maze of threads was too closely packed to enable us to determine whether any were inserted into the actual periphery, but in another case we have

observed this insertion. The lens itself was globular, showing neither sutures nor zones of discontinuity; it was homogeneous, and opalescent. Both eyes exhibited the same condition, the Schiötz tension was 60, and the retina and choroid degenerate. The child was blind.

The suspensory ligament is normally formed of discrete strands of cobweb-like threads, which, originating far back from the ora serrata and vitreous, run forward in the valleys between the ciliary processes, to be inserted into the anterior and posterior capsule at some distance from the actual periphery. One strand lies on each side of a ciliary process, so there are about 140. The strands diverging to the two lens surfaces enclose a space, the so-called canal of Petit. This conformation recalls the threads of a loom expanded for the passage of the shuttle.[1]

This arrangement would tend to draw the lens backwards, but this bias is neutralised by a group of fibres which pass forward from the posterior lens surface, to be inserted into the tips of the ciliary processes, forming a kind of fan where the two systems cross. We have seen threads coming forward which would seem to confirm this view of the anatomy of the suspensory ligament, which we have taken from Salzmann.[2]

The fibres of the zonule can be seen only when the lens is displaced or through a congenital coloboma. We have for a long time endeavoured to see these structures with the slit-lamp through an operative coloboma, but have only found one example, a coloboma produced by the iridectomy which accompanied a sclero-corneal trephine. Occasionally in an artificial coloboma the zonular fibres can be seen with the ophthalmoscope, but not with the corneal microscope.

The best view of a normal zonule is found in a case of congenital coloboma of the iris. It is a most fascinating structure seen shimmering in the beam of the slit-lamp, and it is perfectly visible under the magnification of the ordinary loupe if carefully illuminated with a focal beam from a half-watt lamp. It can be seen with a + 20 lens behind the ophthalmoscope. It is obvious that it is impossible to make an exact drawing of the zonular ligament, all attempts must be diagrammatic. Such an essay has been made in Fig. 66. The division into strands is better seen in this type of case than in subluxation, because owing to the increased length of the threads the segregation into bands tends to become obscured. A decentred

[1] Occasionally the filaments are uniformly disposed and the division into strands cannot be determined.

[2] In another case a series of filaments were seen attached to the anterior lens surface coming forward to the ciliary body in an artifical coloboma.

lens with a perfect suspensory ligament is shown in Fig. 67. The original was made not with the slit-lamp, but with a loupe. In another similar case each filament bifurcated where it was attached to the lens, and upon each filament there was a pigmented node.

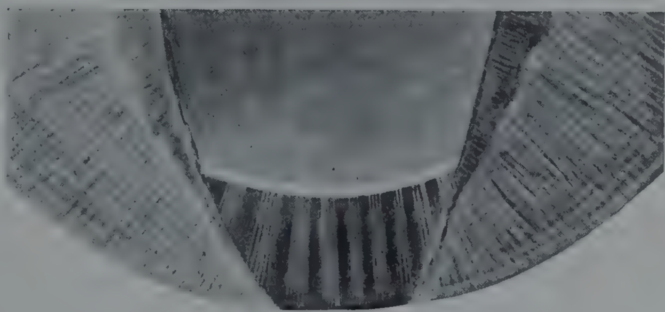


Fig. 66.—A congenital coloboma of the iris, showing the bands of the suspensory ligament.

When seen with the ophthalmoscope the periphery of a subluxated lens is surrounded by a dark border; the exact opposite is the case in focal light, the lens has a bright edge. This phenomenon is due to the physical fact that when light strikes a refracting medium at an angle greater than the critical, which for glass is about 40 degrees, the beam is not refracted, but totally reflected. The edge of the lens is rounded, and in this situation light falls upon it with an incidence greater than the critical angle, and is reflected by the posterior limiting surface of the capsule along the back of the lens. Hence the equator of the lens is opaque to light, and fundus light is obstructed, giving the dark border. It is important to realise this optical truth, for we find total internal reflection not only at the lens margin, but at the periphery of internal lens nuclei to which we shall have occasion to refer in a later chapter. Like many of the drawings which illustrate this book, those showing the zonule are not actual representations of what is seen, but an interpretation thereof: they show in one presentation the combined effect of several slit-lamp observations.

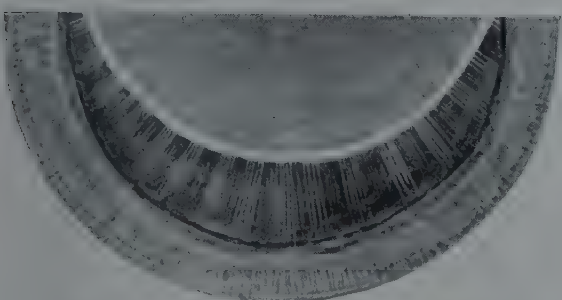


Fig. 67.—A congenitally decentred lens, showing a normal zonule.

The real appearance is given in Fig. 68. We see the corneal prism and behind it the half-section of the lens suggesting a grindstone. To the left of the lens there is a caustic-like wisp of light

trailing away in a parabolic curve to the left. This is the path of the light totally internally reflected from the edge of the lens. Below the bright surface of the lens we see the fibres of the zonule in an endless vista, like trees in a dense forest, some of the fibrils attached to the anterior surface of the "grindstone," others passing behind it. To the left of the filaments the membranes of the vitreous can be brought into focus.

FIG. 68.—The same case as it actually appears with the slit-lamp. To the right the corneal prism. Centrally the grindstone-like section of the lens. To the left a wisp of light, totally reflected from the edge of the lens. The lower edge of the lens is demarcated by a bright line. Below, to the left, we may note the vitreous impact lines.

The Pathological Zonule.—In a subluxation of the lens the suspensory ligament may be perfect, imperfect, or absent. We have already seen a case with a perfect structure, and we propose to call this a *decentred lens.* In Fig. 69 we see another example which we will term *ectopia lentis.* Here the zonule is imperfect in both eyes. A faint striation was seen with the ophthalmoscope. The tendency to run in bundles is well marked, but the strands are far fewer than normal and some are broken. The third type, *subluxation,* has no ligament. Fig. 70 is a case of familial subluxation of the lens. No fibres can be seen in the situation of the suspensory ligament, but there are vestiges of the pupillary membrane. It is stated that these are present in 20 per cent. of the cases of congenital dislocation of the lens. Another cause of subluxation is shown in Plate IV, C and D. The filaments are present in a rudimentary form, mere thickened

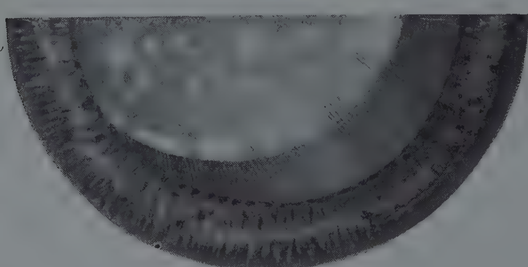
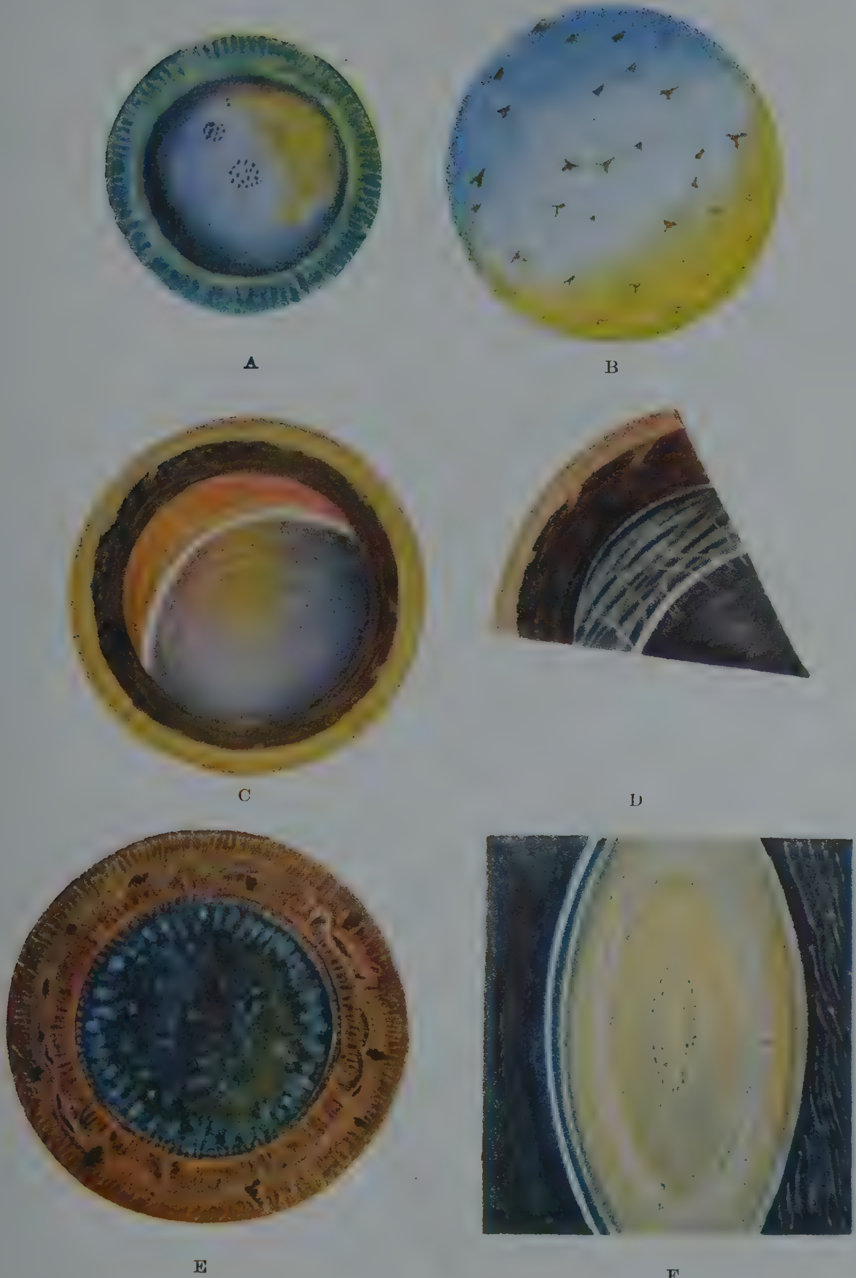


FIG. 69.—Ectopia lentis with a rudimentary zonule.

PLATE IV



A.—Pigment stars on the anterior capsule. Vestigial remains of the pupillary membrane. B.—The "stars" magnified 35 times. C.—A congenitally subluxated lens with rudimentary zonule and maldeveloped iris (partial aniridia). D.—A more highly magnified drawing. Both C and D were made from the view given by the loupe, and D shows that the vitreous can be seen with the loupe. The membranes are visible between the lens and the iris margin and are seen to be speckled with brown pigment. This case was never examined with the slit-lamp. E.—Cataracta Coronaria and Cœrulea. F.—The same in optical section. A wreath-like embryonic cataract is seen centrally.

stumps, wholly useless. The iris is in a state of arrested development consisting of the retinal layer alone in the pars pupillaris, with the addition of an amorphous structureless layer in the pars ciliaris. The drawings were made with loupe magnification and illustrate the fact that the vitreous structure can be examined with this instrument alone.

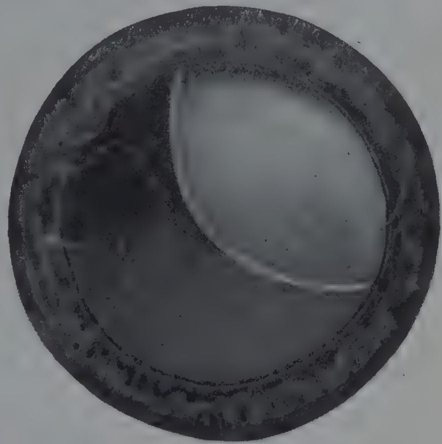


FIG. 70.—Subluxation of the lens. There is no trace of any zonule. Vestigial remains of the pupillary membrane.

The suggested classification of dislocated lenses according to the development of the suspensory ligament is not wholly academical, but has a clinical significance. A lens with a sound ligament is likely to remain in its normal position, and to give considerable difficulty in extraction. A lens without any restraining bonds is apt to be a wanderer sooner or later, and may give rise to sudden glaucoma. Its extraction should be easy in comparison with the removal of the last type. Those lenses which possess an imperfect but functional zonule will occupy an intermediate position in these respects. It is obviously dangerous to attempt to needle a lens which is wholly unsupported in the eye and merely floats in its normal position. No one should operate upon a case of dislocated lens without making a careful examination with the slit-lamp.

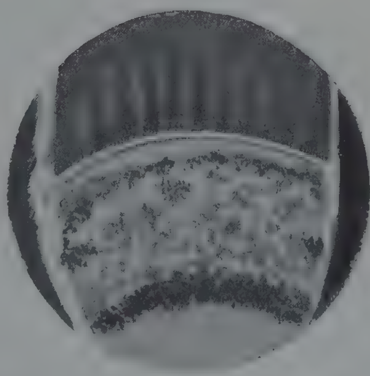


FIG 71.—An iridectomy has been performed for seclusion of the pupil. The lens is covered with pigment, especially at the margin of the pupil. Above, the filaments of the zonule have become matted together into bands.

In some cases of chronic cyclitis the fibres of the ligament may become matted together so that the strands are not now bundles of fibres, but flat ribbons. Some years ago we performed iridectomy to relieve an iris bombé. The patient recently came up for examination and her present state is shown in Fig. 71. There has been some shrinking and displacement of the lens with consequent exposure of the zonule. This shows the altera-

tions described, each strand being represented by a band. This change must narrow the channels round the lens, and if the process continued a complete diaphragm would form, and the lens would be driven forward by the intra-ocular fluid. In another case, in which a large fragment of steel had been removed from the vitreous chamber with the giant magnet, the lens had shrunk and become displaced. The whole zonule had become matted together into a complete membrane.

These observations may have some significance in the development of secondary glaucoma.

The Retro-lental Space has been alluded to in the chapter on inflammation. We propose to defer its further consideration till the vitreous is described.

CHAPTER X

THE NORMAL LENS

THE Zonular Lamella of the Capsule.—In some cases of traumatic dislocation of the lens, and often after intra-capsular extraction, we fail to find any fibres of the suspensory ligament attached to the lens. This is due to the fact that they are inserted, not into the actual capsule, but into its superficial layer—the *zonular lamella.* As long ago as 1882 E. Berger, by macerating the capsule in a solution of permanganate of potash, showed that it was composed of lamellæ. In 1883 Fuchs demonstrated the fact that in irido-cyclitis the capsule split up into two or three lamellæ. Meesmann, reported in the *Bericht der Deutschen Ophthalmologischen Gesellschaft*, 1922, p. 9, gives an illustration of the zonular lamella torn from a dislocated lens.

A similar case was shown by Barton at the Leicester Meeting of the Midland Ophthalmological Society in 1925. Goulden reports two more in the *Transactions of the Ophthalmological Society*, 1925, and a series of cases of separation of the lamella in glass-blowers has been published by Elschnig and others. The following case is of great interest. A man with glass-blowers' cataract, upon whom Mr. Martin Young of Birmingham had performed an iridectomy, was sent to us for an examination in respect of compensation. In examining the lens with a + 20 lens behind the ophthalmoscope we noted some peculiar striæ on the anterior capsule.

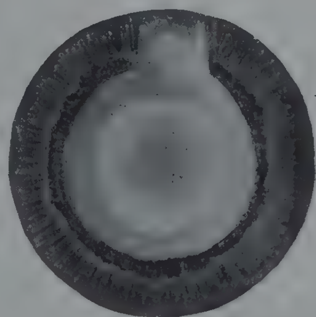


FIG. 72.—A case of glass-blowers' cataract, as seen with a + 20 lens behind the mirror of the ophthalmoscope. Some striations were figured in the original drawing, but are difficult to see on the reproduction. These were caused by separation of the zonular lamella of the anterior capsule.

The appearance noted and the glass-blowers' cataract are shown in Fig. 72. Examination with the loupe showed what appeared to be a detached flap of capsule. This is drawn in Fig. 73. Examination with the narrow beam of the slit-lamp showed clearly (Fig. 74)

that the condition was a separation of the zonular lamella which is seen detached at the periphery and curling up in the centre of the lens. We know from the researches of Vogt and Kranz that the anterior and posterior capsules are profoundly affected by the action of infra-red rays. The slit-lamp most definitely establishes the existence of a zonular lamella which can differentiate from the true capsule. Meesmann and Schwalbe suggest that this lamella has a mesoblastic origin and that it is derived from the fibres of the zonule, which in turn is said to be developed from the unpigmented cells of the ciliary body.

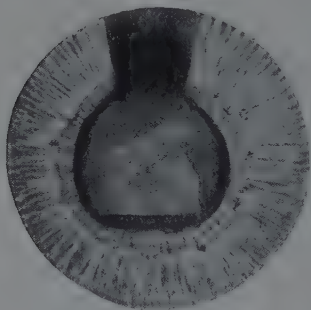


FIG. 73.—The same seen with the loupe under the illumination of a half-watt lamp. The zonular lamella is seen peeling off in the centre of the pupil.

We have several times seen a detachment of the zonular lamella in cases of chronic irido-cyclitis with a shrunken lens. In Fig. 75 the lens has shrunk, and below we see a white mass. This is the detached lamella, and we may note that the greatly stretched zonular threads are inserted not into the lens, but that they pass over the shrunken

FIG. 74.—An optical section of the same lens showing the lamella curling off from the periphery.

FIG. 75.—A shrunken lens. The white mass below represents the zonular lamella. The fibres of the zonule are seen to be inserted into the white mass.

lens and are inserted into the detached lamella. Figs. 76, 77, and 78 are taken from an eye which had suffered from chronic irido-cyclitis after an accident. The pupil is spanned by a perfectly

FIG. 76.—A pellucid membranes panning the pupil, which is in all probability the zonular lamella detached from the shrunken lens.

FIG. 77.—The shrunken lens spotted with dots of pigment.

transparent pellucid membrane of extreme tenuity, upon which course a few new-formed vessels arising from the iris. The iris margin is luted down to this membrane by pigment. The pupil was occluded and glaucoma was present. A shrunken cataractous lens with a deeply corrugated capsule was clearly seen through the membrane, separated from it by a wide interval. The capsule was spotted with pigment. For clarity the membrane is shown in Fig. 76, the lens in Fig. 77. In reality the two were seen simultaneously. The slit-lamp section is seen in Fig. 78. A very thin membrane, far more tenuous than the normal capsule, occupies the plane of the pupil, curling up slightly along the pupil crater. Behind this we have an optically inactive dark zone, followed by a thickened crenated line, the shrunken capsule covering an opaque lens. After an iridectomy no trace of the structure could be found in the pupil

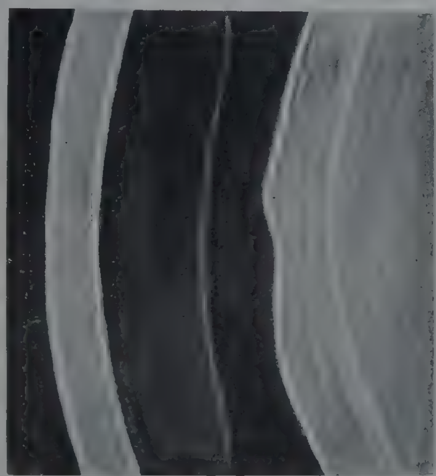


FIG. 78. An optical section of the same case. To the left the corneal section. Centrally the very fine membrane, probably the zonular lamella. To the right the shrunken lens with a thickened distorted capsule.

area, but a few vestiges were discovered round the margin of the pupil.

It is obvious that the structure is highly elastic and retracts as soon as its continuity is severed. The fact that it curls up tightly when detached is another proof of elasticity. It is difficult to believe that this delicate diaphanous structure can be the result of the inflammation. We have seen similar membranes in other cases of irido-cyclitis. The vessels on the membrane are probably all that remains of an inflammatory process in the pupil area; the exudate has absorbed, leaving the clear tissue of the capsule below. One would have anticipated that by reason of the increased tension the diaphragm would have bulged forward, but such was not the case. The iridectomy did not reduce the tension, and we may conclude that the seclusion of the pupil had nothing to do with the glaucoma.

The Architecture of the Lens

It is essential to obtain a clear idea of the anatomy of the normal lens, and from our own early experience we are well aware that the subject is difficult for the beginner. The lens can be examined in two ways: the *narrow beam* shows the organ in profile, and enables us to study it by a series of sagittal sections. The *broad beam* is used to investigate the character of the successive surfaces of the lens, we examine it in concentric layers. The two methods combined enable us to build up a complete picture in three dimensions.

It has long been known that the lens is composed of strata, it has been likened to an onion. We can now differentiate, not only belts of varying refractive index, the *discontinuity zones* of Vogt, but definite regions with well-defined boundaries and characteristics. Purkinje recognised that the lens had an anterior and a posterior reflecting surface which show his famous images. Hess, using a bright linear source of light, demonstrated a third mirror in senile lenses due to reflection from the face of the nucleus. Gullstrand added several lines of discontinuity, but it was the genius of Vogt that devised the adjustable slit, and with the narrow beam he mapped out the lens into well-defined regions.

A distinction must be made between the now well-known landmarks and mere lines of optical discontinuity. The lens is from

birth constantly growing; layer upon layer are laid down by the equatorial epithelial cells, just as the rings of a tree increase year by year. It is reasonable to suppose that any alteration in nutrition will modify the chemical nature of successive additions, and with the chemical the optical properties. In some children, and occasionally in adults, we find a lens almost homogeneous in aspect. Another child of the same age, and apparently equally healthy, has a lens with a most complicated succession of zones. It is reasonable to suppose that the period of growth in the former child has been characterised by an extremely regular nutritional state, whereas the opposite may be the case in the latter child. This may be a fanciful theory, but the following case supports it. A girl of eighteen was found to have a lamellar cataract situated more peripherally than is the rule. It was estimated, by virtue of its location, that this abnormal deposition of fibres took place at the age of thirteen. *Subsequent* inquiry elicited the information that at thirteen the patient had suffered from a cerebral abscess secondary to a mastoid inflammation, and that she had undergone several operations and was confined to bed for a year. The serious, prolonged illness and the lamellar cataract coincided in point of time, and must be

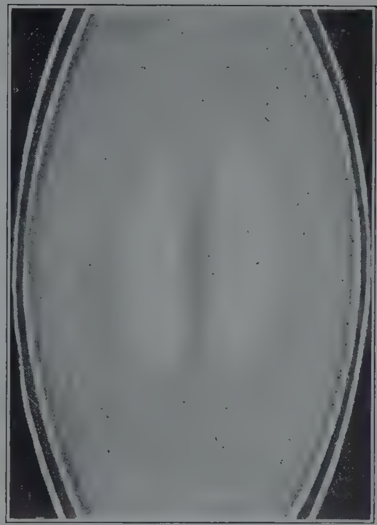


FIG. 79.—A lamellar cataract in an adolescent caused by a cerebral abscess at the age of 13. The embryonic nucleus has become too distinct in the process of reproduction.

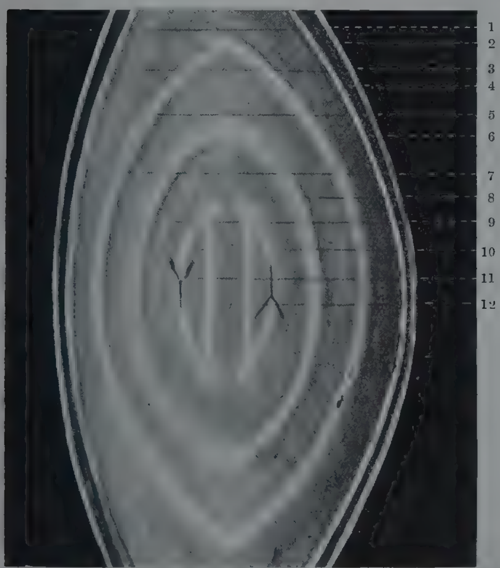


FIG. 80.—A diagram of Vogt's "Conventional Lens."

1. Anterior capsule; 2. Posterior capsule; 3. Anterior subcapsular line; 4. Posterior subcapsular line; 5. Anterior cortex; 6. Posterior cortex; 7. Anterior adult nucleus; 8. Posterior adult nucleus; 9. Anterior fœtal nucleus; 10. Posterior fœtal nucleus; 11. Anterior embryonic nucleus; 12. Posterior embryonic nucleus.

held to have more than a casual connection. Her lens is shown in Fig. 79.

The well-known association of lamellar cataract with ridged teeth and with tetany supports the view that the architecture of the lens can be in some measure an index of the life history of the individual.

The *Conventional Lens* as described by Vogt is shown in Fig. 80, a diagram modified from his well-known drawing. It is rare to find such a perfect lens, but we have seen one in a young woman of twenty-five, which is shown in Fig. 81 and may be used as a typical example. Here the zones are well defined by white condensation lines. This topography is infrequent. In the majority it is impossible to define all these zones as sharply limited layers. It is a mistake for the beginner to try to discover in any one lens all the details of the lens anatomy that we are about to describe. He will see a certain structure clearly in one patient, in another this will be difficult to find, but other details are apparent.

FIG. 81.—An optical section of a typical normal lens.[1]

The Examination with the Narrow Beam

The Capsule.—If the anterior edge of the lens seen in section be accurately focused both as regards illumination and vision, it takes the form of a thin, glistening, bluish line. In the aged it sometimes has a yellow tinge. This is the anterior capsule. It is perfectly constant in all lenses. Under the capsule there is a dark space, a zone of extreme transparency.

The Subcapsular Line is a thin, somewhat yellowish line found behind this space. It has been called the reduplication line by

[1] Miss Ida C. Mann thinks that the embryonic lenticuli have not in reality pointed tips and that fibres cross from one to the other, shutting in the central lucid interval, which corresponds to the primary primitive lens fibres. (*Lecture at Oxford Slit-Lamp Course*, December 1926.)

Graves, and by Vogt the cleavage line. It varies in appearance; in the young it is almost as blue as the capsule, but it does not scintillate, in the older the subcapsular line is less transparent than the capsule and has a yellowish shade. The distance between this line and the capsule is not constant. In some lenses they are closely approximated, in others there is a wider interval between them. This is not entirely a matter of age, although on the whole the tendency is for the lines to be closer in age than in youth. The outer edge of the subcapsular line is usually sharp. This is generally the case with the inner margin, but occasionally, and this is more common in young lenses, the inner edge is not well defined, but tends to merge into the general yellowish aspect of the cortex. The radius of curvature of the subcapsular line is shorter than that of the capsule, so that the dark interval is greater at the equator than at the pole.

Vogt states that this line is always present, and that it can be seen if the slit is sufficiently narrow. This may be the case, but it needs an arc-lamp to get sufficient light through such a narrow slit. With the ordinary Nitra lamp we have sometimes failed to define the line. These cases have generally been children with highly transparent and homogeneous lenses, but we have made the same observation in old persons. We have invariably found the line in adolescence, adult life, and middle age, but at the two extremes it has occasionally been absent.

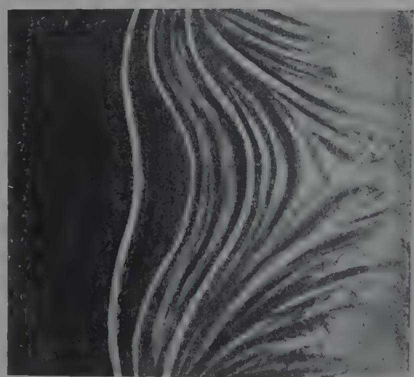


Fig. 82.—A section of the lens in a case of cataracta complicata. There is central shrinking, and the subcapsular line is seen caved back and separated from the capsule by a large fluid cleft.

Little is known of the nature of the subcapsular line. It is certain that it forms a definite physical stratum in the lens and is not merely an optical effect. In a case of cataracta complicata shown in Fig. 110, there was a white opacity in the posterior capsule and cortex with degenerative changes in the vitreous. In a few months the whole lens became opaque with a central, clear, funnel-shaped depression. The slit-lamp section is seen in Fig. 82, and shows that there is axial contraction dimpling the anterior capsule. The subcapsular

line caves backwards and is separated from the capsule by a large fluid cleft. On the other hand, the line cannot differ much from the capsule in the chemical sense, for, as seen in Fig. 83, it can be freely eroded by a fluid cleft.

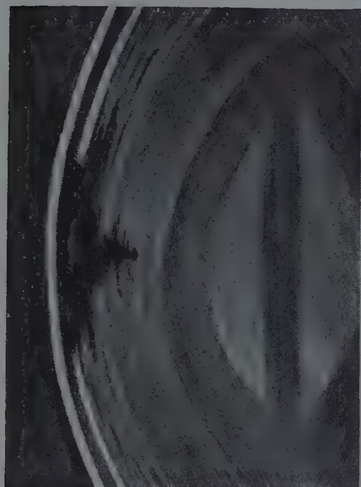


FIG. 83.—A fluid cleft in a case of soft secondary cataract. The cleft is eroding the subcapsular line, and also the adult nucleus.

The Cortex.—The next zone Vogt calls the cortex. This term is not a very happy one when translated into English, for it introduces some confusion with the "cortex" that we associate with operations, but it has now passed into general use.

The cortex differs in colour from the deeper layers of the lens. Generally, and more especially in the adolescent lens, it is yellowish in contrast with the blue-grey of the deeper layers. Even in a senile lens we often find a deep yellow cortex and a steel-grey nucleus behind it. On the other hand, we have lenses in which the central portions are yellow, merging into brown, while by contrast the cortex is blue and perfectly transparent.

The Adult Nucleus.—Behind the cortex we come to the zone which Vogt calls the *Alterskern.* Unfortunately in the translation of his atlas the word has been rendered as "senile nucleus." This gives an entirely false impression, for this layer is present in infants after the age of about ten, and has nothing to do with senility. In children this zone is not yet well differentiated, and probably the adult nucleus in childhood is the equivalent of the cortex in the older lens, a layer which has not appeared at twelve. In the fully developed lens, and still more in the senile organ, the adult nucleus is sharply demarcated from the cortex and frequently by a well-defined condensation line of a yellowish colour. This point will be emphasised when we come to consider the surfaces of the lens.

The Fœtal[1] *Nucleus.*—The next zone is called by Vogt the *outer embryonic nucleus.* The region is present at birth and it is confusing to have two embryonic nuclei, so we propose to name it the *fœtal nucleus.* In young lenses this zone is often defined

[1] We have in the past called this zone the "infantile nucleus," but the term "fœtal" seems more consistent with the terminology used by embryologists. *Embryonic* is applied to structures developed up to the end of the first three months of gestation, *fœtal* to the last six months.

by a white condensation line, and it appears to take the place of the adult nucleus of the fully developed organ as *the main dividing line between cortex and nucleus*, using these terms in their older sense.

The Embryonic Nuclei.—The central part of the lens is occupied by the two embryonic nuclei separated by the central lucid interval. In the conventional lens they are outlined by white condensation lines. They have the form of plano-convex lenses placed with the flat surfaces facing each other. The posterior is larger than the anterior. These internal lenses can be seen in all persons except when pathological central sclerosis has obliterated the lens architecture. It is rarely that they are seen sharply defined, generally the edges are blurred, and the limit of the nucleus can be detected only by the position of the sutures.

On the flat surface of the anterior nucleus we frequently find a small scintillating axial opacity. Vogt finds it in 25 per cent. of all cases, and calls it an *anterior axial embryonic cataract.*

The Central Lucid Interval.—This is a dark, vertical area in the exact centre of the lens. It is a region of perfect transparency and is absolutely constant in all lenses with the exception of those in which abnormal sclerosis has shrouded structural details. This zone is the oldest part of the lens, representing the earliest stage in development.

The Curvatures of the Zones of the Lens.—If we study the curvatures of the lines which limit the nuclear surfaces, we shall note that in each case as we pass from the periphery towards the centre the radius is shorter, the curvatures of the inner nuclei are greater than those of the outer, and that all the posterior curves are stronger than the anterior. In some juvenile lenses the peripheral zones take a reverse curve towards the equator. The gradually increasing curvature is not shared by the embryonic nucleus, which is concentric with the fœtal.

We must now consider the cause and effect of this arrangement. The development of new fibres from the equatorial epithelial cells of the anterior capsule is continuous from the earliest life till advanced senility, if not actually till death. Were there no compensating mechanism the lens would eventually become monstrous and destroy the eye. When the organ has attained its full size increase in growth is neutralised by compression of the inner layers, which lose water, till eventually with the exception of a thin layer of cortex the whole lens is sclerosed, and complete presbyopia results.

Whereas the sutures of the lens branch near the periphery, and the fibres arise from the sutures, it is a mathematical corollary that compression is greater at the periphery than at the pole. Not only does the increasing curvature begin as soon as the fœtal nucleus is covered by new fibres, but the actual difference in radius is greater in the aged than in the young.

We shall see that when normal sclerosis becomes abnormal and extreme, with the formation of nuclear cataract, the curvature of the adult nucleus is very acute, in fact it approaches the globular form.

The lower animals have simple sutures and consequently concentric zones of discontinuity.

Sclerosis and increase in refractive index are not of necessity equivalent terms. Freitag is of the opinion that the difference in refractive power between the cortex and nucleus is actually greater in the child than in the adult.

As the lens grows its surface becomes less convex; each successive zone from within outwards is flatter than the one central to it. Were this alteration in curvature not compensated by a proportionate increase in the index of refraction, the total dioptric power of the lens system of the eye would diminish. As a matter of fact this equilibration takes place and the dioptric power of the lens remains approximately constant. In some cases in later years compensation to some extent fails; increase in refractive index does not keep step with flattening of surface and the eye becomes more hypermetropic.

It may be taken as axiomatic that Nature never creates unnecessary complication of structure and there must therefore be a reason for the intricate anatomy of the lens. There can be little doubt that the varying curvatures of the lens zones combined with appropriate indices of refraction are the means adopted to correct spherical and chromatic aberration.

The two plano-convex lenses of the embryonic nucleus challenge comparison with similar lenses used in all optical systems to correct spherical aberration. It is true that when the lenses are in air we place them with their convex surfaces facing each other so that the entering and emerging pencils may leave the glass at approximately equal angles. In the crystalline lens the position is reversed. We must therefore assume that the refractive index of the embryonic nuclei is less than that of the fœtal nucleus and of the lucid interval.

The Child's Lens.—Fig. 84 represents the lens of a child of six.

It is different from the conventional lens that we have studied. In this particular child the subcapsular line is absent. We were not able by the most careful focusing, and using the narrowest slit that would pass sufficient light to illuminate the subject, to detect the faintest suggestion of this line. It must not be concluded that this is normal in the child's lens; in general the subcapsular line is as obvious as in the adult. The lens shows only four well-marked zones instead of the usual five. The separation into cortex and nucleus takes place not at the adult, but at the fœtal nucleus. This demarcation is frequently so sharp that the edge of the fœtal nucleus is seen during retinoscopy and suggests a slight lamellar cataract. It has been stated that this appearance is caused by incomplete cycloplegia. We have taken children who showed this feature and made certain that they were effectively under atropine and have seen no alteration in the picture. We have also examined them with the slit-lamp, and have found no trace of lamellar cataract. What is observed is the edge of the fœtal nucleus, showing slight total internal reflection.

FIG. 84.—The lens of a child. No subcapsular line was seen in this case.

Although one child has an almost homogeneous lens, while another of the same age possesses a beautiful specimen of intricate structure, yet the total transparency would appear to be similar in each case. We cannot associate lack of visual acuity with complication of structure. We do not yet know exactly how the child's lens develops into the adult structure. The lines of discontinuity are to some extent merely expressions of optical distinction and cannot always be taken to have an anatomical let alone a physiological significance.

Examination with the Broad Beam

The full width of the slit is employed to examine *the surfaces of the lens*: the capsule, the face of the adult nucleus, and the limits of the embryonic nucleus.

The Anterior Capsule.—Seen *en face* in mirror light the anterior capsule has a surface which is finely rugous. The appearance is best described by comparing it to that corrugated glass which is chosen for a bathroom window; it also suggests certain forms of leather surface, such as the covering of the case of an ophthalmoscope. It is in consequence called *the shagreen*. Peripherally we see nodules among the finer grain of the shagreen, and within the interstices of the pattern the epithelial cells are manifest as small dots, particularly when viewed with A 3, a magnification of 30. The shagreen is lustrous and has a yellowish tinge. It can be easily seen with a loupe under the focal illumination of a half-watt lamp. The shagreen was recognised long before the advent of the slit-lamp, and it was taught that iridescence of the anterior capsule was an indication of cataract. This view requires modification. When the anterior capsule is illuminated by a very strong light and examined with the loupe, slight iridescence is not pathological, but a marked play of colours is an early sign of changes in the lens. Under the slit-lamp anything beyond the very slightest mother-of-pearl shimmer is abnormal.

To demonstrate the shagreen we place the slit-lamp at a wide angle and make the patient so direct his gaze that his line of vision bisects the angle between the visual and illuminating axes and lies in their plane. In order to see as large a surface as possible we may use the light slightly out of focus to get a diffuse illumination. We then sharpen up the focus and search for the cells in bright focal light.

The Posterior Capsule is examined in the same way, but with this difference: we always employ sharp focal light, and we draw the slit-lamp close to the microscope. It is better, if the pupil is not dilated, to use a beam that is somewhat narrow. The pencil of light may be useful in this examination.

The posterior shagreen has a finer mesh than the anterior, and there are no cells. Whereas the posterior mirror is concave the image is brighter and is seen over a smaller area. The posterior shagreen has a golden-yellow colour and is highly lustrous.

Iridescence of the posterior capsule when slight is not abnormal in the old, but when well developed it is, according to Vogt, indicative of a cataracta complicata. We may see a play of bright colours like those of the kaleidoscope with here and there points of metallic

sheen. In old lenses the posterior capsular has a granular appearance and gleams with a bronze-like glint; perhaps "old gold" best describes the colour.

The cause of the shagreen has not yet been explained, but many of the suggested causes can be eliminated. It is seen on both capsules, excluding the epithelial cells as a cause. When the zonular lamella peels off the capsule still shows the shagreen, as was noted in the case of glass-blower's cataract already mentioned. This excludes this structure. Vogt thinks that it is due to the arrangement of the fibres under the capsules: this theory is untenable. In Fig. 85 a case of Morgagnian cataract is drawn. All the fibres of the cortex have been absorbed and the nucleus is floating freely in a clear fluid through which the fundus is plainly visible, and which allows a visual acuity of 6/18. The shagreen is perfect and is highly iridescent. Therefore the lens fibres have nothing to do with the effect. It follows by this process of exclusion that the shagreen is a function of the capsule itself.

FIG. 85.—A Morgagnian cataract. The anterior capsule is irregular in its curvature, and has a well-developed iridescent shagreen. The nucleus shaped like a grindstone is seen to the left.

THE SUTURES OF THE LENS

The Sutures of the Cortex Surface are best seen with the simple loupe in the following manner. Concentrate the light of a 60-watt half-watt bulb upon the anterior capsule. Make the patient gaze half-way between the surgeon and the lamp, and observe with an ordinary loupe, placing the head in such a position that the three lines, illuminating axis, observation axis, and axis of the patient's gaze, are all in the same plane. Move the head up and down till this combination is obtained, when the shagreen will shine out like freshly cast aluminium. Now shift the regard somewhat and focus a shade more deeply. The sutures will be seen like dark veins upon

a dark background. With the slit-lamp we see only portions at a time, and it is not so easy to obtain a general view. The normal appearance of this complex system of sutures is illustrated in Fig. 86.

FIG. 86.—The sutures of the anterior cortex.

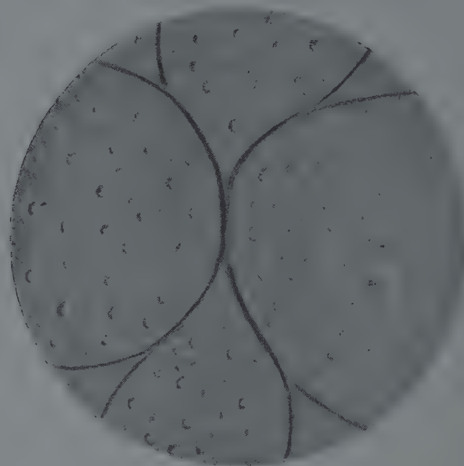


FIG. 87.—The anterior relief of the anterior surface of the adult nucleus. In addition the surface is studded with knobs.

The Sutures of the Adult Nucleus next claim our attention. The limiting surface of the nucleus is prominent in the aged, but is not easy to define in the young. Its position can be found by the fact that it forms the posterior surface of the lens prism. It has in middle-age a *relief* system of sutures. That in the posterior surface is a *reversed relief*. In the one we look down upon ridges, in the other into valleys: the anterior is a cameo, the posterior an intaglio. In addition to the ordinary sutures the adult nuclear surface generally shows raised knobs and bosses.

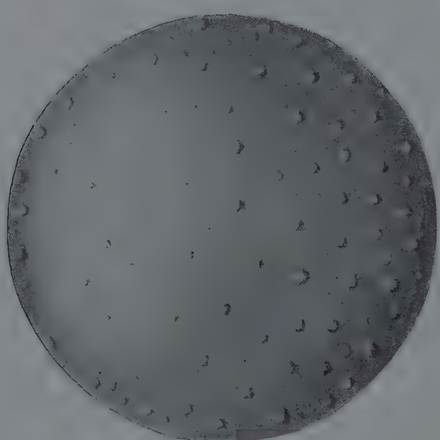


FIG. 88.—The hobnail-boot type of adult nuclear surface. In this case there were no obvious sutures.

A common type is presented in Fig. 87. Occasionally there are no visible sutures, but the whole surface is covered with knobs. Such a condition is seen in Fig. 88. In Fig. 89 the same lens is shown in section and we note that each boss is raised from the surface of

the adult nucleus as a definite prominence, and throws a dense shadow backwards into the lens.

Shadows are projected backwards by any opacity in the eye, whether it be an actual physical obstruction or an optical opacity such as a vacuole or a fluid-cleft. Irregularities in the corneal surfaces may cause an apparent distortion of the surface of the lens, and similarly a warped capsule modifies the shape of objects behind it.

FIG. 89.—The same lens seen in optical section. Each knob throws a shadow backwards. The cortex shows several fluid clefts and spicules. The nucleus is sclerosed, and has a high refractive index causing lental myopia, and a double focus lens.

The surface of the adult nucleus is an extremely important factor in the anatomy of the lens, in that it divides the *nucleus* from the *cortex*, using these words in their general sense. There would appear to be a specific difference between the two regions. The colour is dissimilar, and late in life they differ in texture. The pathological changes in the nucleus are quite unlike those in the cortex, and they react differently to changes of nutrition, to toxæmias, and to the action of light and heat. Thus, if, after an operation for glaucoma, the lens remains in contact with the cornea, and consequently its nutrition suffers, it is not the cortex that first becomes clouded, but the nucleus. On the other hand, infra-red irradiation spares the nucleus but acts deleteriously upon the capsules and cortex. As we shall see later, this specific dissimilarity is shown in the sites of election of varied types of cataract, those found in the cortex in no wise resemble nuclear opacities.

The Sutures of the Fœtal Nucleus.—Vogt says that these are simple in character; they are not visible in a normal lens, but may be the seat of suture cataracts, and are then obvious. In the juvenile lens the surface of the fœtal nucleus takes the place of the adult surface in older lenses, but the division into two dissimilar regions is not nearly so definite as that made by the adult surface.

The Embryonic Sutures, the well-known "Y's," are found on the anterior and posterior convex surfaces of the plano-convex formations that with the central lucid interval constitute the embryonic nucleus. Contrary to what is stated in text books of anatomy, and even in Salzmann's anatomy of the eye, *the anterior Y is erect*, the *posterior Y is inverted.* It is astonishing that this error has been

repeated from book to book, because in cases of lamellar cataract the anterior Y can occasionally be seen with the naked eye, and sometimes both are visible with a loupe. An example is shown in Figs. 124 and

Fig. 90.—The anterior Y showing lens fibres arising from the sutures.

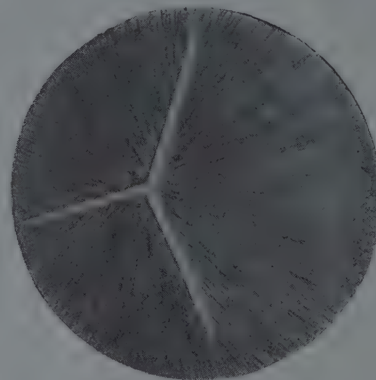


Fig. 91.—The posterior Y.

127. There are few exceptions to the rule that the posterior Y is inverted, and as far as we are aware, the anterior is always erect.

The posterior Y is easily seen when the lens is viewed with the broad beam, but the anterior Y is a difficult object, especially in young, highly transparent lenses. With increased experience it can generally be seen.

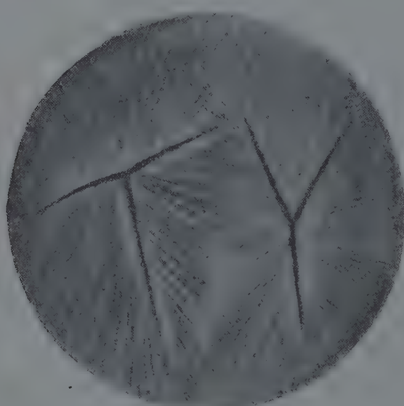


Fig. 92.—An abnormal posterior Y. Either it is inverted or swung through a large angle.

Fig. 93.—A double posterior Y.

The lens fibres are visible springing from the Y's and can occasionally be traced nearly to the periphery.

Vogt in his Atlas figures drawings of macerated fœtal lenses in which the sutures have the same form as the Y's in the adult structure.

Fig. 90 shows the anterior Y; Fig. 91 the posterior. The lens

fibres are seen streaming away from the sutures. Those that leave the tip of the anterior arms are inserted into the centre of the posterior in such wise that all the fibres have approximately the same length. In the young lens the Y's appear as bright, highly refractile bodies, with a dark border, but this arrangement may be inverted, and in older lenses the suture is dark brown. It is the rule for both Y's to be inclined at the same angle.

Fig. 92 shows an abnormality of the Y's. The posterior is in an unusual position: either it is erect instead of being inverted, or it is twisted through a large angle. A double Y is seen in Fig. 93. In this example it is the posterior, but we have seen a double anterior Y. This anomaly is easy to explain, for the suture is not a mere surface formation, but extends deeply into the nucleus. It is important to learn to recognise the Y's, because they are very valuable landmarks, and are constant in position.

Landmarks.—In localising structures in the lens it is necessary to have definite guides. In addition to the Y's there is the central lucid interval, and the surface of the adult nucleus when it is clearly defined. In younger lenses the posterior surface of the lens prism is a useful landmark.

The Arc-line

If we focus the posterior Y and trace its nasal branch downwards till it bifurcates, we discover a white ring situated upon the posterior capsule. This is the arc-line, and marks the spot where the branches of the hyaloid artery were attached to be distributed to the tunica vasculosa posterior. The arc-line may take a variety of forms and may be duplicated. In Vogt's Atlas there are many drawings of the varieties found.

It is obvious that were the arc-line situated at the posterior pole it would interfere with clear vision; hence its situation, on the nasal side and below the pole.

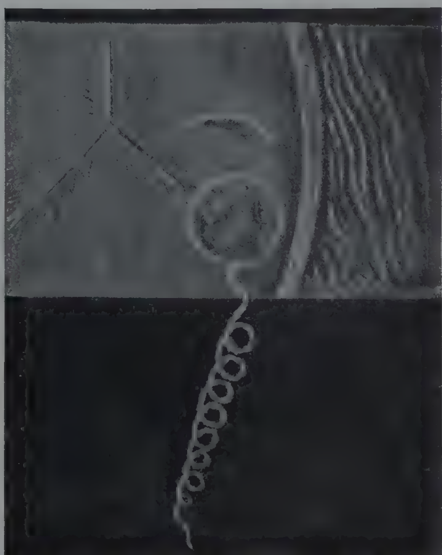


Fig. 94.—The arc-line with a second arc above. The hyaloid artery is very distinct.

FIG. 95.—A similar drawing with a simple arc-line.

The Hyaloid Artery.—Hanging from the arc-line, dangling in the retro-lental space, the hyaloid artery is seen in most children. Later in life it generally drops off, leaving a stump of varying size. Vogt gives the incidence of a visible hyaloid as 75 per cent. It looks exactly like a piece of string coiled into a spiral. It is attached to the capsule and may sometimes be seen depending from the posterior capsule when the lens has been removed by discission. An example is seen in Figs. 142 and 143. Fig. 94 shows the usual appearance of the artery, as seen in many children. Another typical example is shown in Fig. 95. The interesting point about this case is that there was an abnormality at the disc end of the hyaloid. This is drawn in Fig. 96. A yellow strand springs from the disc and ends in a pigmented disc. At first sight it would appear to be extraordinary that the anterior end of the artery should be normal in appearance, while the posterior was strikingly abnormal. This difficulty has been solved by Miss Ida C. Mann, who informs us that when the hyaloid begins to retrogress, it divides at a spot about one-third of the distance from the disc to the lens. This division has taken place here. The anterior part has followed the normal course of development, but the posterior has failed to absorb.

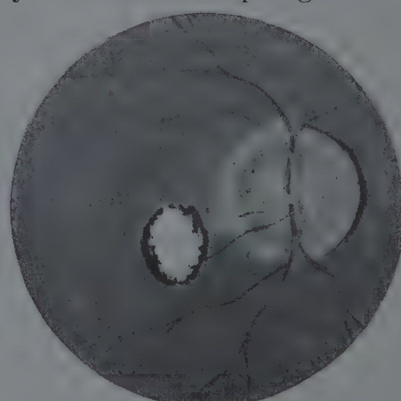


FIG. 96.—The posterior extremity of the hyaloid artery shown in Fig. 95. It ends in a pigmented disc.

CHAPTER XI

THE PATHOLOGICAL LENS

EXAMINATION with the slit-lamp has greatly elaborated our knowledge of cataract. Opacities of the lens may now be classified according to the particular zone they occupy, and we know more about their shape and of the changes that take place as the opacity develops. It will be most convenient to consider cataract according to the anatomical situation of the opacity. Vogt has pointed out that varied types have favoured sites, and that many are confined to definite zones in the lens.

Anterior Capsular Cataract.—It is quite common to find that a lens opacity is confined to the capsule. This may be diffuse, occupying a large extent or even the whole of the capsule. The appearance may be compared to a pane of glass smeared with paste of varying consistency. Localised opacities are sometimes congenital, and then have a white-of-egg aspect, or they may be due to inflammatory changes following iritis, or to the action of various noxæ such as an electric short-circuit. Such a cataract is exemplified in Fig. 97. The patient was quite close to a very severe flash of lightning, and from that date was conscious of something wrong with his eye. It is possible that the opacity may have been caused by the electric discharge. It is stated that such cataracts are generally capsular, and have the shape shown in the drawing. The prolongations may signify the spread of the current.

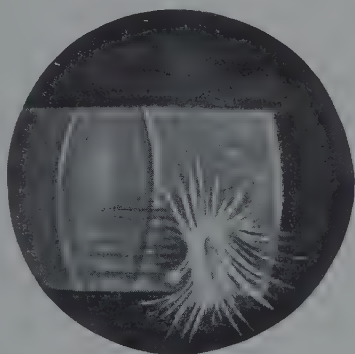


Fig. 97.—An anterior capsular cataract, perhaps caused by an electric discharge.

Anterior Polar Cataract can be studied to great advantage with the slit-lamp. A typical example of the pyramidal type is shown in Fig. 98. A cone of opaque material rises from the level of the

capsule. Deeper in the lens another opacity is seen, the "*imprint*" (German *Abklatsch*). The disturbance which gave rise to the opacity, probably contact with the cornea, took place when the lens was smaller; the capsular change implicated the epithelial cells, and they in turn impressed the cortex immediately beneath, and an opacity developed in the cortex. With the lapse of time new fibres were deposited under the capsule, which travelled forwards taking the polar cataract with it, leaving the imprint behind. As the lens continued to grow, the clear space between the twin opacities expanded and remained as a permanent record of the lapse of time. The situation of the imprint dates the original cataract. There is an imprint in the majority of the cases of anterior polar cataract. These structures are described by Treacher Collins and a microscope section is to be found in Parson's *Pathology of the Eye*, vol. ii, p. 413.

FIG. 98.—An anterior pyramidal cataract (anterior polar) with a deeper "imprint."

A more complicated case is shown in Fig. 99. There is a corneal scar, obviously the scar of a perforation. Under the scar there is an anterior polar cataract to which many of the strands of a persistent pupillary membrane adhere, others appear to be attached to the corneal leucoma. The iris is extensively adherent to the anterior capsule by dense synechiæ. Deep in the lens the imprint is clearly seen. In this case it is probable that an intra-uterine gonococcal infection has caused a corneal perforation, and has in addition to causing the cataract inhibited the normal retrogressive changes in the tunica vasculosa. We have seen several similar cases. The reality of intra-uterine gonococcal infection is confirmed by a severe case of gonorrhœal

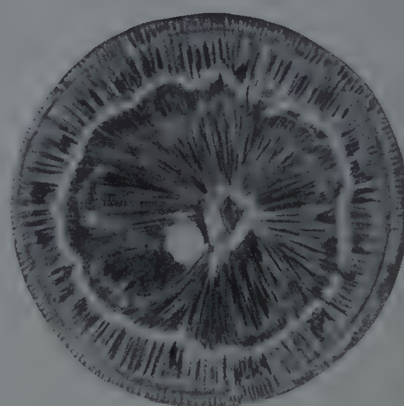


FIG. 99.—An adherent leucoma with anterior polar cataract and "imprint." There is a well-developed pupillary membrane vestige and extensive posterior synechiæ. A case of intra-uterine iritis.

ophthalmia which we treated in a baby delivered by Cæsarean section at the Kidderminster Infirmary.

Vacuolation of the Cortex.—Vacuoles are seen immediately under the cortex. They may be of varied size and shape, and are seen in the senile lens, and in the cataracts which form in young persons as the result of toxæmia, secondary cataracts. In one case we observed a large perfectly circular vacuole in the exact centre of the capsule. Seen in section, it formed a considerable prominence of the lens surface, and naturally it threw a dense shadow backwards. At first we regarded the case as one of central fusiform cataract, mistaking the shadow for a tube-like opacity. We mention this mistake to emphasise the importance of shadows in slit-lamp work. Bedell has published some beautiful drawings of vacuoles (*The Journal of the American Medical Association*, vol. lxxxii, no. 6, p. 363).

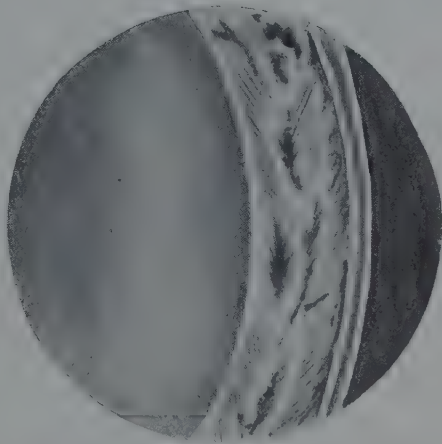


FIG. 100.—Lamellar separation and fluid clefts in the cortex.

The Cortex is the seat of many interesting changes. It would appear that the pathological processes which happen in the cortex are inherently different from those in the deeper nuclei. In the adult lens there is a definite boundary at the surface of the adult nucleus. Each is foreign territory to the other, but the frontier is not inviolate; we have already seen a fluid cleft invading both quarters (Fig. 82), but the case from whom the drawing was made was young, when the barrier is not so perfect as it becomes in later years.

Cortical Cataract.—The earliest stage in many examples of cortex cataract is separation into lamellæ, the *lamellärer Zerklüftung* of the Germans. This is often detected with the loupe examination under focal examination, in fact a better general idea of its distribution is so obtained than with the slit-lamp. The surface of the cortex is seen to be lined with oblique serrations which cross the field diagonally. The appearance suggests that upon the shells of some diatoms, like the teeth of a fine file. If an extreme example is examined under a magnification of 30, it looks like the half-opened

leaves of a book, looked at end-on. Seen in section the cortex has a herring-boned appearance, which is brought out in Fig. 100. A wonderful presentation is given in Vogt's Atlas of some photographs of wax models of Zerklüftung made by Lüssi, at that time First Assistant in Professor Vogt's Clinic at Basel. The lines of cleavage correspond neither with the lens fibres nor with the sutures, and it is difficult to understand the process. Sometimes an advanced stage of lamellar cleavage is accompanied by contraction which distorts the anterior capsule.

Fluid Clefts (*Wasserspalt*).—After a time clefts appear in the cortex which is showing cleavage. Examples are seen in Fig. 100. The edges of the lamellæ become absorbed, and the fluid cleft is surrounded by a kind of fringe, the ends of the unabsorbed lamellæ. Similar clefts are seen in soft cataracts, but they have a different pathology; they are not preceded by lamellar separation and have smooth walls. The senile clefts enlarge and seem to proceed along one of two lines. Several may coalesce and form a large cavity filled with fluid, in fact in some cases the whole of the cortex appears to be fluid in front of an opaque nucleus. The completion of this process is a Morgagnian cataract. This change explains some of the undoubted examples of the disappearance of lens opacities. A central fluid cleft, even if of small size, can be very detrimental to the visual acuity. If, however, the cleft increases and now occupies the whole area of the pupil, it may no longer form an obstruction to the passage of light. The common end of a cleft is to become filled with myeline clumps and to form a spicule, the ordinary striæ of a cortical cataract. Mr. Nicholas Hughes pointed out to us that in certain clefts which contained solid particles convection currents were visible, the particles sinking in one aspect and rising in another. We examined the case and substantiated the observation. Lamellar separation is found not only in the anterior cortex, but also in the posterior.

Lamellar Separation of the Adult Nucleus is quite common, but it is an actual separation of the fibres of the nucleus, and so differs from the same appearance in the cortex. It does not form fluid clefts, and is probably more an optical appearance than an actual precursor of a cataract. In Fig. 101 the appearance is portrayed as it appears in the posterior adult nucleus. The fibres are seen streaming from an opaque suture of the posterior adult nucleus.

Dark anterior spicules are seen, and there are subcapsular vacuoles. The anterior shagreen is highly iridescent.

Cataracta circinata cœrulea.—This uncommon form is shown in Plate V, Fig. C, which was drawn from a patient at the Coventry Hospital, a woman of forty-four. On the surface of the adult nucleus there were a large number of bluish-green opacities in delicate filigree tracery. They tended to an annular form, and the name that we have given them seems appropriate. We have not seen anything of the kind before. The abnormality was confined to one eye.

FIG. 101.—Separation of the fibres of the adult nucleus arising from an opaque posterior relief suture. Spicules in the anterior cortex. Fluid clefts in the lens prism (cortex). Subcapsular vacuoles. Iridescent shagreen.

Cataracta punctata cœrulea and *Cataracta coronaria.* Coronal cataract was so named by Vogt. It consists of peripheral club-shaped opacities forming a sort of wreath chiefly in the adult nucleus. It is associated with the well-known cataracta punctata cœrulea. An example is shown in Plate IV, Fig. E. The optical section of the lens localises the opacities largely in the adult nucleus, Plate V, Fig. F. A wreath of dust opacities is seen in the embryonic nucleus. Such are not uncommon and have no special significance. It is therefore obvious that this type is not, as is commonly supposed, a congenital form, for it is situated in a part of the lens which is as yet unformed in infancy. We have also seen these deposits in a lens which we had examined eight years previously and noted to be free from cataract. These cataracts are apt to be slowly progressive, and we operated upon a case which had gone on to widespread opacity.

Corkscrew-shaped Opacities are occasionally seen in the adult nucleus, often associated with a diffuse streaming opacity, the *cataracta dilacerata* of Vogt. These and many other varieties are figured in Vogt's Atlas. Careful work in the out-patient room will be rewarded by the discovery of these varied and interesting types of cataract.

Suture Cataracts are often very beautiful objects, and may affect most of the sutures. We have so far not seen a suture cataract of the anterior cortex sutures.

The Adult Sutures may become greatly thickened and form a definite brown opacity. Such a cataract is seen in Fig. 102. Here the suture is seen to occupy about a third of the lens prism, and is associated with lamellar cleavage of the adult nucleus. See also Fig. 101.

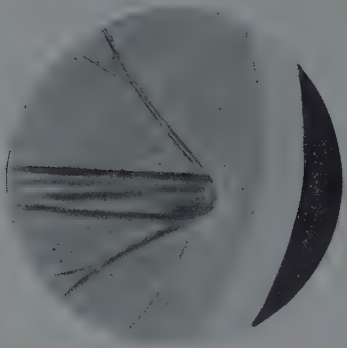


FIG. 102.—An opaque anterior adult nucleus suture.


FIG. 103.—A suture cataract, probably of the posterior adult intaglio.

Fig. 103 shows a suture cataract deep in the lens. It was discovered in a somewhat restless child and could not be accurately localised, but was apparently a thickening of the intaglio of the posterior surface of the adult nucleus. The drawing was made from the ophthalmoscope view.

The Embryonic Sutures, the Y's, form most artistic-looking, feathery, azure opacities. Another type is illustrated in Fig. 104.


FIG. 104.—A suture cataract of the anterior Y.


FIG. 105.—A central cataract with a suture cataract of both Y's. Observed with the ophthalmoscope.


FIG. 106.—The same seen with the broad beam.

In Fig. 105 we have drawn the most extraordinary example of suture cataract that we have yet seen. It was discovered in the Coventry School Clinic. Fig. 105 shows the view with the ophthalmoscope. There is a central globular opacity across which extends

an absolutely geometrical tripolar star with diamond-shaped points. The view with the broad beam shown in Fig. 106 shows that it is a suture cataract of a normally placed anterior Y combined with an opacity of an abnormal posterior Y, abnormal in that it is erect. In Fig. 107 the cataract is seen in optical section. Both eyes were similar. We were so much struck with the symmetry of the opacity that we wondered how far the eye of faith had contributed to the drawing. We have, however, seen the child several times, and have twice examined him with the slit-lamp, and are satisfied that the picture is not exaggerated. The patient had very fair vision.

Fig. 107.—The same in optical section.

Fig. 108 was taken from a boy with normal acuity. The inner nuclei were abnormally blue. The surface of the infantile nucleus is sharply

Fig. 108.—A central cataract on the anterior surface of the infant nucleus. A similar opacity is seen on the posterior surface of the adult nucleus. Both throw a dense shadow backwards.

Fig. 109.—An opacity in the posterior embryonic nucleus.

differentiated by a yellow condensation line. There was an axial opacity on the surface of the infantile nucleus which threw the usual dense shadow backwards. A similar opacity is seen placed

eccentrically far back on the posterior surface of the adult nucleus. Both were of the scintillating type seen in lamellar cataract.

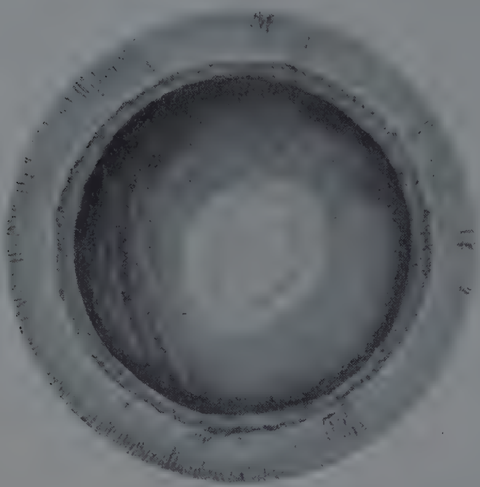


FIG. 110.—A posterior cortical cataract. Eventually the whole lens suffered from cataracta complicata. Degenerating vitreous.

Opacity of the Embryonic Nucleus.—Fig. 109 shows an opacity of the posterior lens of the embryonic nucleus. The anterior lens was normal in aspect. The opacity had a silky cocoon-like texture, and had no appreciable effect upon the acuity, which was 6/9.

Posterior Cortical Cataracts.—These are very common and are often associated with changes in the posterior capsule, and may indicate the commencement of a cataracta complicata. An example of this type is shown in Fig. 110. The central dense white opacity was surrounded by a diffuse nebulous haze. The whole lens eventually became opaque and has been noted with reference to the subcapsular line, Fig. 82. The connection of posterior capsular and cortical cataract with cataracta complicata is very important.

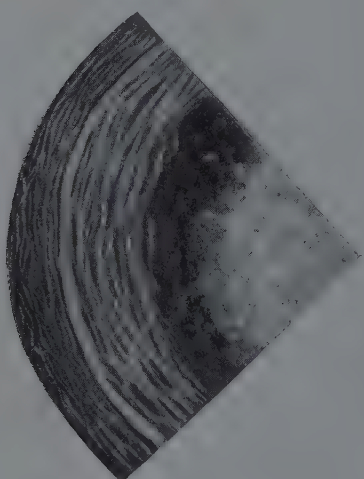


FIG. 111.—A posterior cortical cataract. The opacity bends forward, and is seen as a lace-like opacity in the peripheral part of the anterior cortex. The adult nucleus is also affected, and its edge shows the bright line of total internal reflection. The iris is not shown.

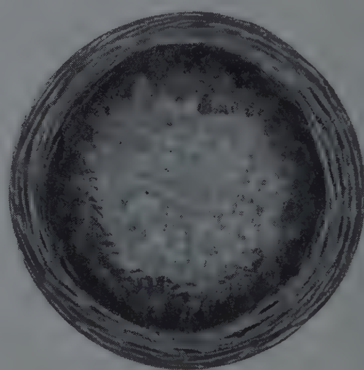


FIG. 112.—The same lens seen with the loupe.

Figs. 111 and 112 show a cataract of the posterior cortex that extends round the equator into the anterior cortex. The forward portion is seen as a fine lacework. The adult nucleus is sharply defined by a bright rim of total internal reflection.

A very common type of opacity in the posterior cortex is seen in Figs. 113 and 114.

Glass-blowers' Cataract affects the anterior capsule, the posterior

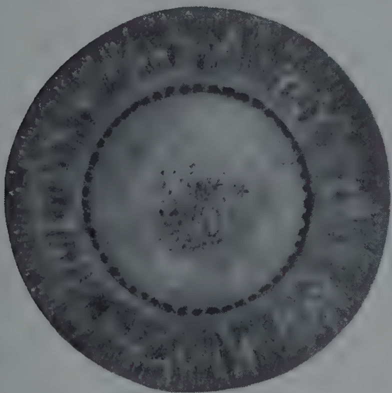


FIG. 113.—Another more common type of posterior cortical and capsular opacity seen with the ophthalmoscope.

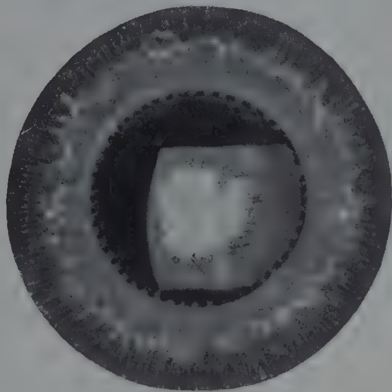


FIG. 114.—The same seen with the broad beam somewhat out of focus to give diffuse illumination.

capsule, and the posterior cortex. It is caused by the action of infra-red rays, as has been proved by Vogt. The general appearance with the ophthalmoscope has been shown in Fig. 72, and we have

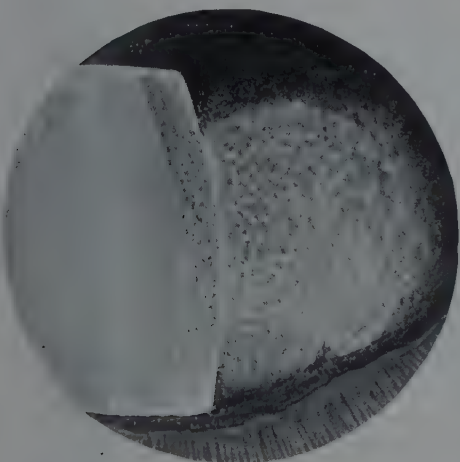


FIG. 115.—Glass-blowers' cataract.

FIG. 116.—The same seen in optical section. Note the thickening of the posterior capsule.

noted the effect of the rays upon the anterior capsule. The posterior capsular and cortical opacity is seen in Fig. 115, and the localisation with the narrow beam in Fig. 116. It will be noted that in addition

to the opacity in the posterior cortex, which had a golden granular appearance, there is a thickening of the capsule, which projects backwards somewhat like a watch-glass.

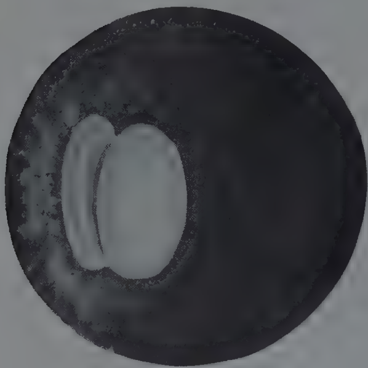


Fig. 117.—A posterior capsular cataract with its "imprint."

Posterior Polar Cataract with "Imprint."—We have already described the anterior polar cataract with its characteristic "imprint." A similar condition obtains with reference to a posterior polar cataract. Two cases of this nature have come under our notice at the Coventry Hospital. In one patient the anomaly was bilateral, in the other it was present in one eye only. The appearance is shown in Fig. 117, as seen with the broad beam; the section is seen in Fig. 118.

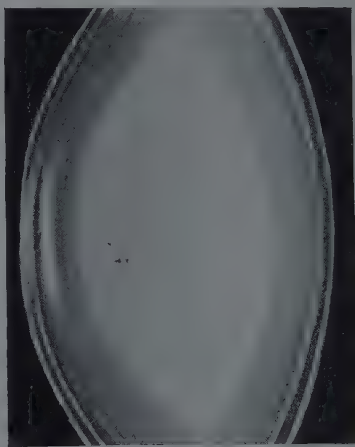


Fig. 118.—The same seen in optical section.

Lenticonus posterior is a very rare abnormality. We had the opportunity of seeing an example at Zürich during Professor Vogt's Slit-lamp Course. Seen *en face* there is at the back of the lens a deep depression surrounded by a broad convex edge, which by virtue of its shape shines brightly in the beam of the slit-lamp. It is like the smooth rim of a washing-basin. Seen in optical section the posterior capsule suddenly bends backwards to form a large cup-like depression. We have not had the opportunity of drawing one from nature, and hesitate to reproduce the appearance from memory after a considerable lapse of time.

Fig. 119.—Lenticonus perinuclearis posterior seen with the loupe.

Lenticonus perinuclearis posterior.—We are indebted to our colleague, Mr. Jameson Evans, for permission to reproduce this interesting case which was examined at the Birmingham

Eye Hospital in 1926. The anomaly was present in both eyes, and from its position, and its similarity to a true lenticonus, we have given it the name of lenticonus perinuclearis posterior. The appearance when examined with the loupe is shown in Fig. 119. The slit-lamp section is shown in Fig. 120. There is an opacity deep in the lens which is seen to be hollowed out like a saucer. The floor is convex, bulging forwards. At first sight we thought that it was a true lenticonus posterior, but careful examination with A 0, which proved very useful for this type of work, showed that the posterior capsule was normal in contour as far as it could be traced, till it was lost behind the opacity. There was a double cup, the posterior being yellowish. The structure is reconstructed and shown diagrammatically in Fig. 121. We suggest that originally this was a true case of lenticonus posterior, but that the growth of the lens has built up new cortex which has left the abnormality behind it, when the capsule, being elastic, would resume its normal curvature. There may be a better explanation. Mr. Evans made an attempt to extract the lens in its capsule, but the capsule burst and the section of the lens under the microscope added nothing to the knowledge gained from the slit-lamp when the lens was *in situ*.

FIG. 120.—The same case seen in optical section. The saucer-like posterior opacity is seen by diffused light. There is an opacity in the anterior cortex.

FIG. 121.—A diagrammatic reconstruction of the lens.

Nuclear Cataract

There are two types of nuclear cataract. One forms rapidly in any adult lens as the result of failure of nutrition. This is typically seen when the anterior chamber is totally abolished and the lens comes into contact with the cornea. The nucleus seen with the broad beam is a brilliant, pearly white, of the type the French call *nacré*. It is opalescent and generally contains fluid clefts. With the narrow beam it is found to be translucent, and of the same character from front to back; subcapsular vacuoles are numerous.

The ordinary type depends upon the physiological sclerosis of the lens. The healthy senile lens has in the nature of things a densely sclerosed nucleus, but it remains transparent, and the details of its normal architecture are still plainly visible. We see the sutures of the embryonic nucleus, the central twin lenses of this nucleus, and the lucid interval. Generally in such a lens the posterior portion has a brown tinge. Under certain conditions the sclerosis is abnormal and is associated with more or less lack of transparency, forming a nuclear cataract. The normal senile lens is often pigmented, and in some cases of nuclear cataract the pigmentation is excessive, causing the brown and black cataracts. An early case of this nature is seen in Fig. 122. The nucleus is surrounded by a clear interval. This is a constant feature, even in an advanced nuclear cataract. (Between the cortex and the surface of the opacity there is a transparent zone which has a dark colour.) In this eye the nucleus was green in the anterior part, and became yellow and eventually brown as we passed backwards. There was a little lenticular myopia but the acuity was still good: 6/9 with −1D. As this lens becomes

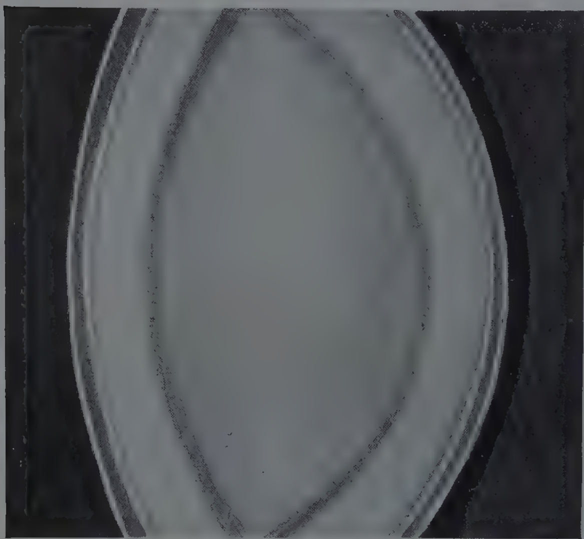


Fig. 122.—Early nuclear cataract.

cataractous the following alteration will take place. The nucleus will become more strongly curved and will advance forwards till there is but a narrow zone of cortex left. Then the surface of the adult nucleus will lose its sharp demarcation. The deeper layers will become invisible on account of the increasing opacity. They will, as far as they can be seen, have a dark-brown colour.

The Lens with a Double Focus.—Under certain conditions the nucleus instead of becoming opaque will alter its index of refraction. Normally the difference in index is slight, but in the senile lens sclerosis may be associated with a rise in the index. The consequence of this change is that the nucleus becomes myopic. When the pupil is dilated the peripheral layers bring rays to a focus behind those that pass through the more highly refractile nucleus. The lens has a blurred linear focus instead of a sharp punctate focus. Often the slit-lamp will reveal the cause of poor acuity, which is not accounted for by any opacity of the lens. The highly sclerosed and over-curved nucleus is plainly visible, and is more defined than the normal nucleus. Fortunately elderly persons have small pupils, and in consequence the clinical result of this lens is increased refractive power, the eye becomes increasingly myopic. A lens of this type was figured in the chapter on the normal lens, Fig. 89.

Fig. 123.—Lamellar cataract with a central denser opacity. Note the reverse curves towards the periphery.

Lamellar Cataract.—We have already pointed out the origin of this opacity. It is caused by nutritional disturbances which exert a deleterious influence upon the normal deposition of the lens fibres. It follows that many varieties may occur, and such is the case. In the common type a wreath of scintillating particles is seen in a zone which corresponds to the surface of the fœtal nucleus. The opacity looks like artificial ice. Not infrequently there is a double wreath, and almost invariably there are well-marked condensation lines which are yellowish in contrast with the grey of the juvenile lens. Not

infrequently the lamellar opacity is associated with a central opacity. Such a case is shown in Fig. 123. Here the main opacity which occupies the whole centre of the lens has a more opaque nucleus, and the particles are larger and denser. The mass shows the reverse curve that Vogt has figured in some of the zones of the normal lens.

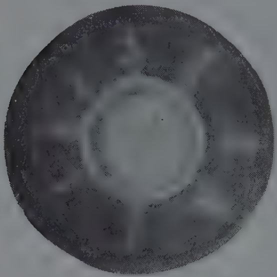


FIG. 124.—Lamellar cataract with riders. View with the loupe. The anterior Y was clearly visible with the naked eye.

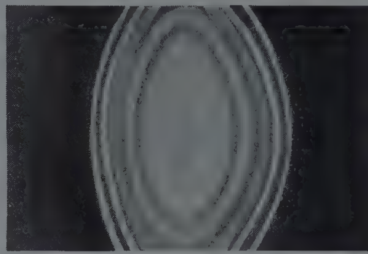


FIG. 125.—The same in optical section.

In another case there is a lens in which the whole of the fœtal nucleus is altered into a semi-opaque scintillating ring. There is a second ring of denser material in the adult nucleus, but this is of ordinary lens material and not the scintillating glistening formation of the wreath.

FIG. 126.—A central cataract, viewed with the ophthalmoscope.

FIG. 127.—The same in *en face* view under the broad beam out of focus. Both Y's are seen.

Fig. 124 is another example of lamellar cataract, as seen with the loupe and focal illumination. The anterior Y stands out conspicuously. The central opacity looks like a disc of Bath stone and is surrounded by a halo. The diffuse riders are shown. In section in Fig. 125 there is a central glistening ring surrounded by secondary zones of condensation.

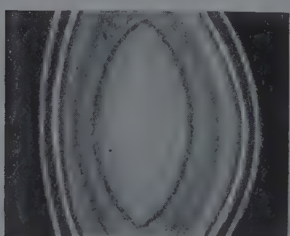


FIG. 128.—The same in optical section.

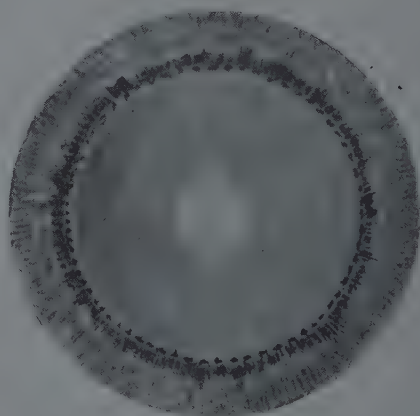


FIG. 129.—A very small central familial cataract seen with the loupe. Note that the opacity is much smaller than the Y which is clearly seen with the loupe.

Familial Cataract.—These opa-

cities are central discoid zones of scintillating particles, and are not of the lamellar type. In Fig. 126 such a cataract is pictured as observed with the ophthalmoscope. The same viewed with the

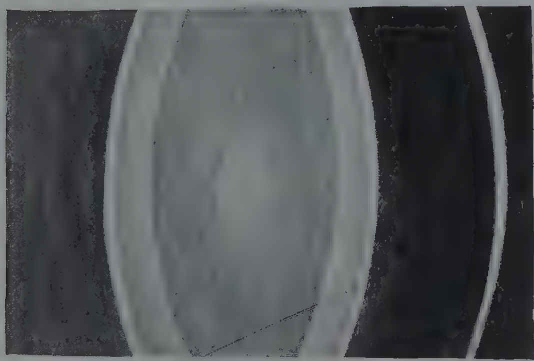


FIG. 130.—The same in section made with the Pocket Slit-Lamp.

broad beam of the slit-lamp is seen in Fig. 127. Here both Y's are visible imbedded in a bluish scintillating mass. Fig. 128 is the section, the opacity forms a complete globe in the centre of the lens occupying the whole of the embryonic nucleus.

A smaller *discoid cataract* is shown in Fig. 129. The central globular opacity is wholly within the position of the Y's, it is much less extensive than the embryonic nucleus. Whatever disturbance caused this opacity must have acted very early in fœtal life. The opacity is seen localised in an optical section, Fig. 130, made not with the slit-lamp, but with the author's pocket slit-lamp. The accurate slit-lamp section is shown in Fig. 131. The Y is seen to be wholly outside the opacity.

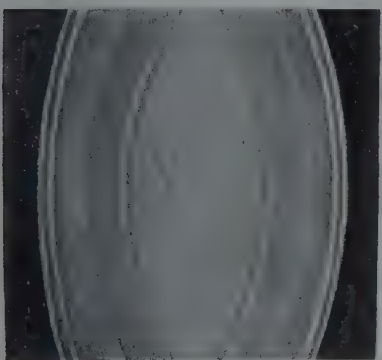


FIG. 131.—The same in slit-lamp section.

FIG. 132.—A notch in the lens showing the zonule. The anterior fibres are absent in the region of the notch. There is an opacity round the notch, which notch affects not only the lens periphery but the deeper nucleus.

Notched Lens.—An example of a notch in the periphery of the lens is shown in Fig. 132. The deformity is present not only in the actual lens equator, but also at the margin of the fœtal nucleus which is demonstrated by its bright edge of total internal reflection. There is considerable opacity in the posterior cortex. The posterior layer of the suspensory ligament is perfect, but the anterior is absent. Only one filament could be seen in the lower portion of the gap. There was a filmy opacity representing three of the ciliary processes which were brown by focal, but black and filmy by retro-illumination.

CHAPTER XII

THE RETRO-LENTAL SPACE AND VITREOUS

THE text books are strangely silent regarding the retro-lental space. Fuchs states that "the posterior surface of the lens is imbedded in the saucer-shaped depression of the vitreous (Fossa patellaris), and is somewhat closely associated with the margin of this depression." Mr. Priestley Smith in conversation upon the subject tells us that "he has dissected scores of human eyes with the express object of examining the vitreous, and in all cases the vitreous was adherent to the back of the lens, and detached only with difficulty." On the other hand, Koby in describing the slit-lamp aspect says: "Behind the capsule is a shallow space which is optically inactive: the retro-lental space. The feebler the illumination the deeper this space appears. With the arc-lamp the fibrous framework of the vitreous appears to be closer to the lens." It is highly desirable to harmonise these two points of view, but before making the attempt we must marshall our facts.

If the posterior surface of the lens be viewed under the narrow beam and brought into sharp focus, it is in a normal eye separated from the face of the vitreous, from the first impact line of the vitreous, by a perfectly dark space. This slit-like void varies in depth in different individuals and tends to be shallow in old age.

If we overrun our lamp and examine in oscillatory light it is occasionally possible to detect horizontal strands crossing the space from lens to vitreous. In other cases the space is filled with delicate strands forming a sort of network. It is very difficult to decide whether this formation is actually in the retro-lental space, or is merely the vitreous framework seen by retro-illumination across the retro-lental space. In another case the vitreous folds were noted definitely attached to the lens. In general when examined with the ordinary Nitra lamp the space is dark and optically inactive (we refuse to use the term "optically empty," a clumsy translation of the German).

After contusions a hyphæma forms in the retro-lental space, and may alter its position with the varied posture of the head.

A hyaloid artery may sometimes be seen swinging freely from the posterior capsule in the retro-lental space after the extraction of the lens. (See Fig. 142.)

Particles float in the space and appear to be in direct association with similar cells in the vitreous.

When there is a perforation in the posterior capsule the cortex swells and protrudes just as it does after discission of the anterior capsule. This would appear to indicate that the retro-lental space contains the same fluid as the posterior chamber.

Cells may appear first in the vitreous, then in the retro-lental space, and finally in the anterior chamber.

The retro-lental space disappears slowly in degeneration of the vitreous and rapidly in inflammation (hyalitis).

We have already seen reasons to doubt the existence of a hyaloid membrane. There are all grades of definition between the surface of the vitreous and the dark area of the retro-lental space. In most young adults and children the zone of demarcation is perfectly definite, in others the dark zone gradually fades into the normal vitreous structure.

It would therefore appear that there may be a definite space full of aqueous, containing at most fine connecting strands, and that this is the usual state in health. In other equally healthy eyes, the retro-lental space contains more formed elements, and merges insensibly into the denser architecture of the vitreous. Finally, there may be no evidence of any localised zone, the whole vitreous is ill-defined and lacking in its normal features. Probably the last category is pathological.

Collecting these facts, it is obvious that although in general all the evidence is in favour of a well-defined zone between the lens and vitreous filled with aqueous, yet it is highly probable that the space is always spanned by fibres which connect the vitreous framework to the lens. This connection may in some cases be abnormally developed, but even in the typical case there is sufficient liaison to explain the fact that the dead vitreous is more or less firmly attached to the lens.

The Hyaloid Membrane has been generally accepted, and some appear to regard it as a kind of vitrified membrane, enclosing the

vitreous in a sort of sac, like the delicate pellicle that lines an egg-shell. The slit-lamp affords no confirmation of this view. We have mentioned the observation of Koeppe, that although the vitrified membranes in the cornea, Bowman's and Descemet's, give a play of colours in polarised light, this effect cannot be obtained upon the face of the vitreous.

When examined with the broad beam, the surface of the vitreous has a characteristic marbled appearance and is often definitely plicated. The folds are shown in Fig. 133, a drawing of the retro-lental space and the face of the vitreous which is somewhat too diagrammatic. Burdon Couper demonstrated the folds of the vitreous face by a study of the entoptic phenomena in his own eye. When the surface of the vitreous is seen in sharp optical section and the eye is at rest, it is defined by a bright line, the edge of a vitreous fold. As soon as the eye moves this line floats up and is seen to be the edge of a gossamer-like membrane which is freely movable and appears to be attached above. It very rapidly returns to its original vertical position, and hangs motionless like a curtain. It is obvious that this impact line does not represent a hyaloid membrane. Often the first impact line is not the brightest, but the third or occasionally the second. If there existed an actual membrane even of the finest texture, it would be seen with the slit-lamp, which distinctly shows the zonular lamella of the capsule. Koeppe suggests that there may be a fine meshwork. We shall see that the vitreous has a great facility for forming films, a fine thread of this structure in the anterior chamber may eventually become a film of extreme tenuity. There is no doubt that the vitreous body is confined by some kind of limiting surface, because a prolapse of vitreous may be ruptured by a slight prick and immediately pour forth. Every operator has had this misfortune. But

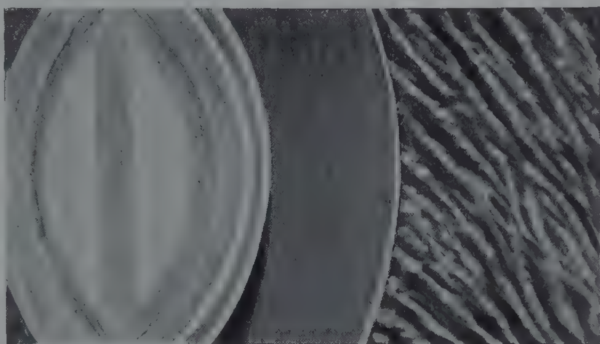


Fig. 133.—A drawing to show the face of the vitreous seen by diffused light from the narrow beam. Above, folds are seen. There is a well-defined retro-lental space, and the impact line of the vitreous face is sharp. This drawing was one of the Author's early efforts, and was made when he thought that he saw a hyaloid membrane. It is introduced to show how a preconceived notion may influence an untrained observation. The impact line is far too distinct, and it should take the general form and direction of the membranes shown behind it.

the same argument applies to a drop of fluid and questions of surface tension may be involved. We can only conclude that, as far as the evidence afforded by the slit-lamp is valid, there is no hyaloid *imperforate* membrane. Other considerations suggest that there is absolutely free access to the aqueous into the vitreous and that a cellular infiltration of the vitreous is almost invariably accompanied by the presence of cells in the retro-lental space.

The Vitreous

Under suitable conditions of illumination the vitreous is visible to the naked eye when the pupil is dilated, and more especially when the lens is absent. It can be examined with a loupe, but can be seen in detail only with the corneal microscope.

The anterior third of this structure is alone available for examination with the ordinary slit-lamp. To see the posterior portions special technique must be adopted. In the ordinary clinical examination the axis of the slit-lamp must be approximated to the microscope as closely as possible. The limit is reached when the illuminating lens just fails to touch the drums of the microscope. A narrow beam of medium width is adopted and when the pupil is undilated it must be as narrow as is possible consistently with adequate illumination. The posterior capsule is brought into sharp focus and the light and microscope focus racked in *pari passu* till the structure of the vitreous comes into view. Considerable practice and much experience are necessary to interpret what is seen. The healthy structure should be constantly explored and then the abnormal will be detected by its departure from the normal.

Under purely physiological conditions we may find a varied picture. In most patients we observe a series of floating membranes which with the narrow beam take the form of filaments. Another form is shown in Fig. 51. Here the vitreous framework consisted of fine filaments, the whole having the appearance of a bunch of cotton waste. In yet another form the filaments are thicker and nodules are here and there seen on the threads.

In the *Transactions of the Ophthalmological Society*, 1925, there is an article by Bedell upon the vitreous, which is fully illustrated. It is obvious that pictures of the vitreous call for a highly developed technique, and require a specially trained artist.

The Pathological Vitreous.—Degenerative processes are best

studied in cases of high myopia. The normal architecture fades and gives place to ill-defined clouds; the membranes break up into filaments and fragments which no longer wave from a fixed point, but drift about freely. The whole process of disintegration can be watched in a case of exudative choroiditis. A slow degeneration takes place in many old individuals, and the end result closely resembles myopic disintegration. (See Figs. 141 and 145.)

Asteroid Hyalitis (Benson's Disease).—In this disease the vitreous is filled with bright globules which are difficult to focus with the slit-lamp and cannot be perfectly defined because of their dazzling reflection. Their appearance has suggested the name, which is singularly appropriate. The globules are obviously not crystalline, and they are not composed of cholesterine, but probably of a lipoid compound. Most cases of *synchysis scintillans* are of this nature. The cases we have seen have all been in old patients suffering from choroiditis.

CHAPTER XIII

THE EFFECT OF OPERATIONS AND INJURIES UPON THE EYE

THE slit-lamp affords valuable information regarding the conditions present after an operation or injury which cannot be obtained from the older methods of examination. This is especially true in the lens, the retro-lental space, and the vitreous.

Siderosis.—Yellow pigmentation is seen in the neighbourhood of a fragment of steel imbedded in the cornea. This disappears when the foreign body has been removed. Rust stains are visible on the anterior capsule, and also in the lens substance, when the eye contains a fragment of iron which is disintegrating. Siderosis is in general accompanied by increased flare in the aqueous and by bedewing. Siderosis may be detected very early with the slit-lamp, and may give timely warning of the presence of iron in the eye. Increased flare alone, and a history suggesting the possibility that the eye has been hit by a fragment of iron, have revealed the presence of an intra-ocular steel splinter.

In the cornea the slit-lamp is valuable to locate the exact position of a *foreign body*, and may determine its nature. Foreign bodies can be removed from the cornea with the help of the slit-lamp and microscope, using objective F 55, a magnification of 9. The best method to employ is sometimes indicated by the view with the slit-lamp which may demonstrate that the fragment is partly in the anterior chamber.

Perforating Wounds.—The examination of the corneal prism, both with the broad and narrow beam, enables the track of a foreign body to be traced in detail, and it is generally possible to state definitely that a fragment has or has not perforated the cornea. Its wound of entry is seen on the epithelial surface, and its exit on the endothelial. The only difficulty is to discriminate between the actual path and the shadows thrown by the surface wound. In most cases there is some distortion in the region of the exit wound on the endothelial surface, with the result that the endothelial cells are

visible over an unusually large area, and are remarkably obvious. After a certain lapse of time, probably measured in years, the visible track of a perforation in the cornea disappears and the scar of the wounds of entry and exit are alone visible. This fact is, as we shall see, of great importance from the medico-legal standpoint.

FIG. 134.
The corneal prism showing a perforation by a fragment of steel.

Often a wound of the iris is noted, and tears and incisions of the pupil margin. If the patient is seen within a few days of the accident the anterior chamber is found to be full of pigment granules, which eventually either disappear or are deposited upon the back of the cornea, the iris, and the anterior capsule. We examined a woman ten minutes after a perforation of the eye with a curtain pin. There was a perforating wound in the cornea, a wound in the iris, and at the bottom of the hole in the iris the lens was seen to be already opaque. The anterior chamber was full of pigment, showing the usual convection stream. The pigment was visible in the aqueous for a week or more, gradually getting less in amount. The spread of the lens opacity was studied from day to day, till eventually a rosette-figure formed deep in the lens.

The track of a foreign body can be traced through the anterior capsule, the lens substance, and the posterior capsule. The route of a fragment of steel through the eye is illustrated in Figs. 134 to 136. The subject, an elderly man, had been struck in the eye by a flying fragment of steel from some work he was chipping. This was localised in the vitreous by Sweet's method, and removed by the Haab technique with the Mellinger ring-magnet. In Fig. 134 the corneal prism is illustrated. The wounds of entry and exit and the track through the cornea are plainly shown, and it is obvious that the cornea has been perforated. This observation was confirmed by finding that the endothelial cells were visible over an unusually wide area. Fig. 135 demonstrates the pouting wound in the anterior capsule, and the path through the lens and the exit are shown in

FIG. 135.—The perforation in the anterior capsule made by the same fragment.

Fig. 136. The posterior cortex in the neighbourhood of the exit wound was becoming opaque and soft and herniating into the retrolental space. The lens substance was getting bronzed, but in

FIG. 136.—The track of the same fragment through the lens, and its exit wound behind. The posterior cortex is softening and becoming opaque by reason of the inflow of the posterior aqueous.

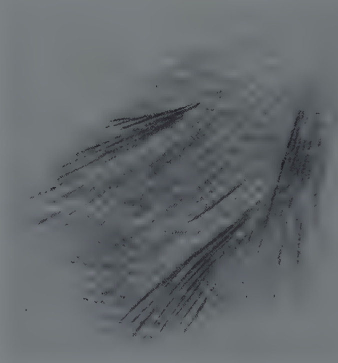


FIG. 137.—The lens fibres breaking up after a perforation of the lens.

this particular example we could not see the bundles of separating fibrils.

Often when the lens has been wounded we can trace step by step the disintegration of its substance. The lamellæ separate and the individual fibres are seen in golden-yellow silky bundles. The appearance is shown in Fig. 137. This case of perforation was followed with the slit-lamp to its conclusion, total absorption of the lens with excellent acuity. A later examination showed a curious condition. At the lower pupil margin there was an effect suggesting that the lens had slipped down, which is indicated in Fig. 138. The upper margin of the supposed lens showed the bright rim of total internal reflection, and above it the posterior capsule was seen as a black curtain covered with

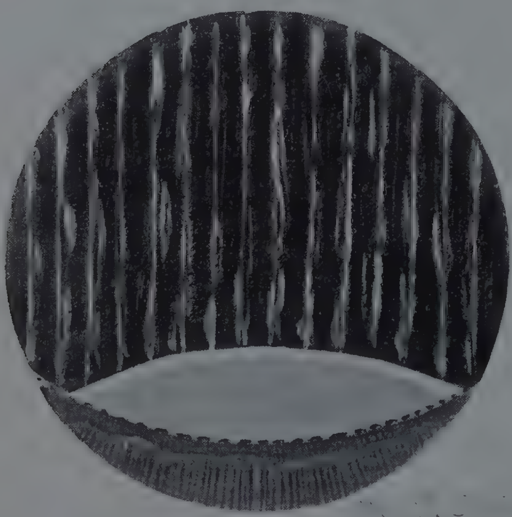
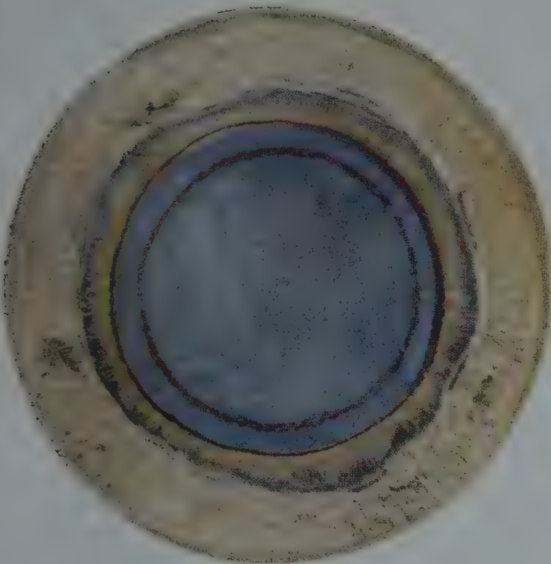
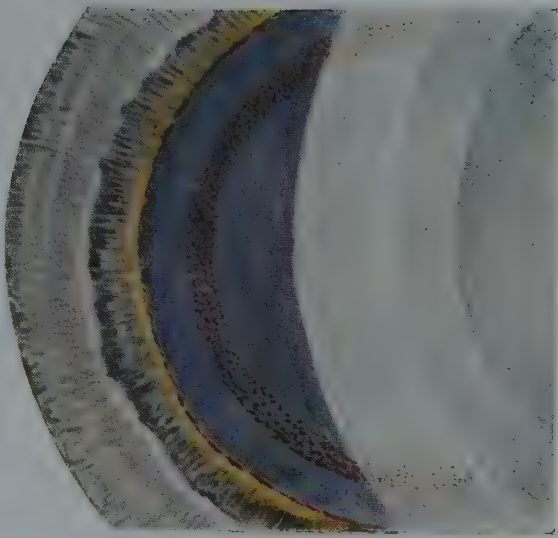


FIG. 138.—Silver-like folds of the face of the vitreous after absorption of the lens. The anterior capsule is folded over below, giving the appearance of a lens edge.

PLATE V



A



B

C

D

A.—A Vossius' ring seen with the loupe. B.—The same seen with the slit-lamp. The corneal prism is not seen; the lens prism appears on the right, and on its surface we note the pigment dots. C.—Cataracta Cœrulea Circinata. D.—An unusual type of Cataracta Cœrulea.

vertical, glistening, silvery folds. After a cataract extraction, when the posterior capsule is folded, this appearance is frequently noted. Fig. 139 gives the sectional aspect of the case. The lens-like appearance was caused by the anterior capsule folding over, and its edge gave the rim of total internal reflection which in section is seen as a caustic-like curve of light streaming away to the right. In the centre the posterior capsule is shown as a sinuous line. The retro-lental space is obvious, and behind it the first impact line of the vitreous which frequently suggests a hyaloid membrane. This section illustrates the fact that often after absorption of the lens the vitreous does not come up to the back of the capsule, but that a retro-lental space remains. Later we shall illustrate another example.

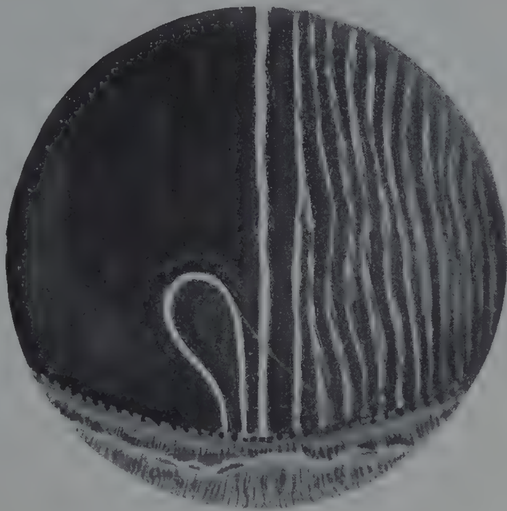


Fig. 139.—The same in optical section.

Vossius' Ring.—Occasionally after a blow upon the cornea a brown ring is seen on the anterior capsule just under the region of the sphincter of the pupil. There is considerable difference of opinion regarding its nature. Some consider that it is formed of iris pigment, while others regard the coloration as the result of an effusion of blood. A Vossius' ring is figured in Plate V, Fig. A, as seen with the loupe. The drawing was made from the eye of a boy who had sustained a blow upon the cornea. The view with the broad beam of the slit-lamp is seen in Plate V, Fig. B. There was no sign whatsoever of any hæmorrhage and the brown ring was composed wholly of pigment grains from the iris. The ring disappeared in a few weeks.

Fig. 140.—Streaks of blood on the posterior capsule after a perforation of the sclera, seen with the ophthalmoscope.

Perforation of the Sclera gives characteristic signs when examined with the slit-lamp. Striations are seen in the vitreous which according to Vogt are pathognomonic of a perforation. Fig. 140 is taken from a case in which the sclera had been wounded by a fragment of metal which lodged in the eye. It was removed with the ring magnet by the posterior route. The drawing shows the appearance with a + 20 lens behind the ophthalmoscope. Streaks of blood are plainly

FIG. 141.—The same lens seen with the broad beam of the slit-lamp. The posterior capsule shows striations which are probably actually in the vitreous. The vitreous is degenerating, and is infiltrated with blood cells and pigment granules.

visible. The slit-lamp picture is seen in Fig. 141. At an early stage there was a well-marked retro-lental space, but at the time the drawing was made this had disappeared. The posterior capsule shows a diagonal striation bronzed above, streaked with red blood below. These streaks appeared to be on the posterior capsule itself, but Dr. Franceschetti, Professor Vogt's first assistant, examined this drawing and came to the conclusion that the striations were in reality in the vitreous. In other cases that we have examined the striation was definitely in the vitreous. Here the vitreous is rapidly disintegrating, and is full of blood cells and pigment granules. After

some months there was nothing abnormal to be seen, except patches of pigment upon the posterior capsule.

In another case of severe contusion of the eye a series of vertical rugæ were seen with + 20 looking like the ridges left on the sand by an ebbing tide. The posterior capsule was diagonally striped exactly as in Fig. 157.

Hæmorrhage into the Vitreous Chamber is common after accidents and contusions. It may be confined to the retro-lental space, where, as we have already seen, it may form a massive collection like a hyphæma. This shifts its position with the posture of the head. On the other hand, it may be definitely located behind the retro-lental space and gives the impression that it is confined by a membrane. This is a strong argument that there is some kind of partition between the vitreous and the retro-lental space, probably of the reticular type suggested by Koeppe. When we are faced with an opaque vitreous we have to decide upon its nature: is it blood, exudate, or tumour growth? Here the slit-lamp will generally answer the question. When strongly illuminated with the focal ray, the surface of a mass of blood has a golden, granular appearance of extreme beauty, one absolutely typical of a collection of blood in the vitreous. In addition red masses may be plainly seen, and streaks of scarlet blood.

Conditions seen after Removal of the Lens.—These vary considerably after discission of soft cataracts and extraction of senile cataract. The slit-lamp is of great value in these cases, for it enables the operator to obtain accurate information regarding the conditions present, and to model his methods accordingly.

The anterior capsule is obviously much thicker than the posterior. After extraction by either method the anterior capsule reflects focal light strongly, and has a glistening white appearance. The posterior capsule is tenuous and often looks quite black. If it is plicated the edges of the folds glisten like silver as in Fig. 138. After some lapse of time cyst-like formations are seen on the anterior capsule—*Elschnig's pearls.* See Fig. 143. Although these look very opaque in focal light, they are seen in an optical section to have thin walls which collapse after discission.

After the evacuation of a soft cataract in an adolescent, it is not uncommon to find a very deep retro-lental space, in fact its depth may be the original space with half the thickness of the lens;

FIG. 142.—An optical section of an eye from which the lens has been removed by discission. The drawing is somewhat diagrammatic. To the left we see the face of the vitreous with an almost normal concavity. Centrally the two capsules have fused but peripherally they are separated. A hyaloid artery hangs in the very wide retrolental space.

in other words, after a perfectly performed operation in a young person the vitreous does not come forward, but remains in its original position. This has a very important bearing upon operative technique, for in a case of this nature it is possible by introducing a Ziegler's knife tangentially behind the capsule to cut forward and remove the opacity without touching the vitreous. Such an operation need not be followed by a prolapse of vitreous into the anterior chamber. A case of this nature is shown in Fig. 142. The patient was a woman of thirty-three with lamellar cataract. The lens absorbed slowly after a single discission and was not evacuated. The optical section shows that the two capsules have united in the centre, but separate at the periphery where there is a bunch of Elschnig's pearls. Behind the capsule, which hangs vertically, there is a large retro-lental space, and in it the hyaloid artery depends from the centre of the capsule. The patellar fossa is seen on the left, showing a well-marked concavity which disappeared after some weeks. The white line strongly suggests a hyaloid membrane, but it waves back freely with every movement of the eye. Fig. 143

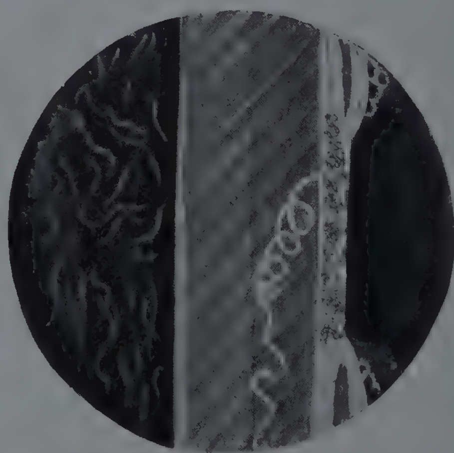


FIG. 143.—The same seen with the broad beam. The rugous surface of the vitreous is well marked. The surface of the anterior capsule is highly iridescent, and on its surface Elschnig's pearls are seen.

shows the face of the vitreous with its characteristic rugæ, and the shadow thrown by the beam. The pearls are clearly seen, and in the original painting the strong iridescence of the face of the anterior capsule. Here we have another proof that iridescence is not caused by lens fibres.

After the extraction of senile cataract in the majority of cases the vitreous comes close up to the posterior capsule, and there is no retro-lental space. This agrees with our observation that this space tends to be shallow in old age.

Vitreous Prolapse into the Anterior Chamber.—Bedell states that whenever the posterior capsule is wounded after extractions the vitreous prolapses into the aqueous. This is in the main true. It is most exceptional to find the anterior chamber free from vitreous after a discission of the posterior capsule, if we examine with the slit-lamp within a month or so of the operation. It is not so common at a later stage, and we can only conclude that in some cases the vitreous returns to its proper place. In some juvenile cases, as we have seen, there is a deep retro-lental space, and in these with care the capsule can be incised without any vitreous prolapse. We have seen this several times, but even in young individuals it is the rule to find traces of vitreous in the anterior chamber.

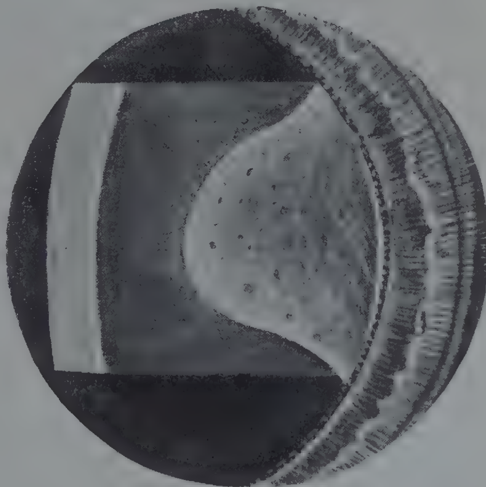


FIG. 144.—A vitreous prolapse after extraction of cataract. The prolapse is not diffuse, but is confined into a globe as by some definite pellicle, probably the meshwork suggested by Koeppe.

Vitreous may prolapse in two forms. There may be a diffuse tuft of vitreous, or it may be strictly confined as if in a bag. Vitreous in the aqueous may be recognised by reason of its refringence, and by the specks of brown pigment which are invariably present. In some cases after a clumsy operation we may find the anterior chamber half filled by a sac of vitreous.

Fig. 144 shows a large prolapse of vitreous into the anterior chamber after a discission following an extraction of a senile cataract. The bag-like protuberance is speckled with pigment, and within it

we see the fibrils of a degenerate vitreous. In this case there was some inflammatory reaction, for the aqueous flare is much exaggerated. Fig. 145 was drawn from the fellow eye from which also a cataract had been removed. Here we have an opaque capsule, and we see that the two layers are separated by cell proliferation. There is here no retrolental space to allow discission without wounding the vitreous, which was degenerate. The drawing shows fine fibres, dots, and clouds.

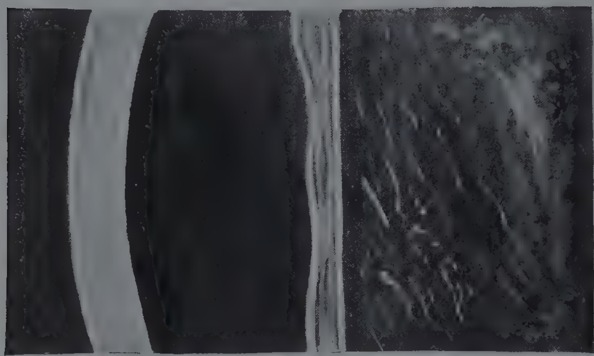


Fig. 145.—An aphakic eye. The two capsules have not approximated, but are separated by proliferation from the epithelial cells, and are semi-opaque. The vitreous is degenerate, and full of clouds and small fibrils.

Fig. 146 is another case of vitreous prolapse. Four years previously the child's lens was needled once, and the posterior capsule was not touched. The *en face* view with F 55, a magnification of 9, is seen in Fig. 147. There is a dense white anterior capsule round the periphery. In the centre the posterior capsule shows fan-like folds. It is perfectly transparent. Away to the right there is a black area, and in this there is a faint cloud just visible with the loupe.

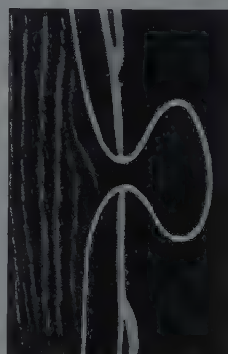


Fig. 146.—Prolapse of vitreous through a hole in the capsule, after removal of a lamellar cataract by discission.

Fig. 148 shows what is not at all an uncommon condition, one which shows the danger of discission through the cornea. A cataract was extracted eight years previously and good visual acuity attained. The patient has never given the remotest cause for anxiety, and the complication was discovered during a routine examination with the slit-lamp. Stretching from the corneal scar made by a discission operation through the cornea there is a tent-like, filmy, funnel-shaped, transparent membrane. Upon it are seen the characteristic pigment dots which stamp the film as vitreous and not as capsule. It is attached to the surface of the *anterior* capsule. The probable genesis is as follows: the knife withdraws a streak of vitreous and

this structure seems to have a wonderful capacity for forming films from mere threads. Cases of this kind have been figured by American writers. It is obvious that a condition like this may be dangerous and it is difficult to remedy, for these tenuous films may refuse to yield to the edge of a Ziegler knife.

FIG. 147.—The same eye seen with the loupe. The white area is the anterior capsule which reflects light strongly. The fan-like membrane is the posterior capsule. To the right there is a dark space, and within it a small cloud. This is a vitreous prolapse seen with the loupe.

Glaucoma after Discission of the Lens.—After a discission operation the gradual dissolution of the lens fibres can be watched with the slit-lamp. Occasionally in the case of lamellar cataract and of certain familial cataracts the opaque particles that cause the scintillating wreath become very opaque and hard-looking, and are deposited upon the iris, and may not absorb for a very long time. Some seem to remain permanently. Generally the lens fibres separate and large clefts appear. Strands of cortex wave in the aqueous and gradually dissolve. Sometimes the edges of these strands form a delicate network which gets finer and finer till it disappears. It is not usual to discover small particles of cortex floating in the aqueous. When they are present in any quantity they cause glaucoma. Fig. 50 illustrates a case of this nature. The patient, a young boy, had received a blow upon the eye and the lens was found to be partially dislocated backwards. The anterior chamber was full

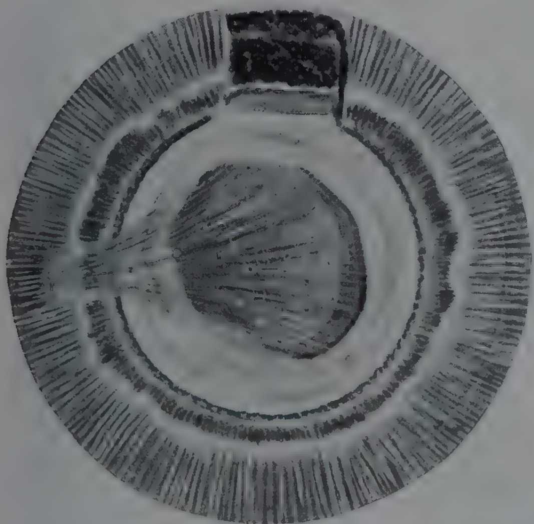


FIG. 148.—A fan-like film stretching from a corneal scar and spreading tent-like to the anterior capsule. This developed after a discission of the lens capsule.

of yellowish flocculi, and the angle of the chamber was seen to be choked by a deposit of cortical material. The tension rose and paracentesis was performed. The tension at once sank to normal, and did not again rise, although for some days a smaller number of flocculi were present in the aqueous. We have seen one case that showed no sign of glaucoma, although there were a number of flocculi floating in the aqueous.

CHAPTER XIV

THE VALUE OF THE SLIT-LAMP IN MEDICO-LEGAL CASES

ALL cases referred for report after accidents with reference to compensation should be examined with the slit-lamp. If in a court case the expert witness on one side has made such an examination and medical evidence for the other side has omitted to use the slit-lamp, an immediate opening is given to an up-to-date counsel to discredit the value of evidence gained from what he could point out was an incomplete investigation.

We have seen how the slit-lamp can at once decide the question as to whether a fragment has actually perforated the cornea or not, and that in some cases an approximate date for the perforation can be fixed. In the lens certain time limitations can be defined : for example, a lesion deep in the lens covered by clear lens cannot be of recent date.

The exact nature of inflammatory deposits and of iris synechiæ can be discovered and it may be possible to show that such could not have been the result of a comparatively recent accident. The presence of striæ in the vitreous points to a wound of the sclera. In a large number of conditions the slit-lamp gives accurate knowledge which cannot be gained without it, and the value of accuracy in medico-legal questions cannot be overrated. The production of definite measurements obtained with the micrometer eyepiece may prove to be the deciding factor in a doubtful case.

The conclusive nature of slit-lamp evidence is exemplified in the following three cases :

A man came to the Coventry Hospital complaining that while engaged in repairing telephone wires he had been struck in the eye by a fragment of copper wire, and that he had noted that sight was failing in this eye. A greenish-blue stellate cataract was found in the centre of the pupil, and it was suggested that this was a copper cataract. The case was examined with the slit-lamp and the appearance is shown in Plate V, Fig. D. The opacity is wholly within the

posterior border of the lens prism, and is therefore in the adult nucleus. It is covered by the whole of the cortex, which is perfectly clear. Obviously it could not have been caused by a recent perforation. No sign of a corneal scar was found, and traces of a similar cataract were present in the fellow eye. The cataract was an atypical form of cataracta punctata cœrulea. A copper cataract has a most characteristic form streaming out from the centre in rays which correspond to the major folds of the back of the iris. The man was told that no claim for compensation could succeed and that his disability was due to natural causes.

A patient was sent to us for examination and report. We found that he was suffering from siderosis, the eye was blind, and the lens cataractous. There was a hole in the iris and a nick in the pupil margin. With the loupe two small cicatrices were seen close together, and were localised with the pocket slit-lamp upon the anterior and posterior surfaces of the cornea. Another small scar was discovered. The patient gave a history that eight years previously a fragment of steel had been removed from the eye with the ring-magnet. The obvious inference was that one fragment had been extracted, but that there had been a second which had remained in the eye. Fortunately the case-book at the Coventry Hospital showed that careful drawings had been made which showed the nick in the pupil but not the tear in the iris, which was therefore probably due to another accident. There was no history of a second accident, but those surgeons who work in industrial districts know that it is far from uncommon to find metallic foreign bodies in the eye when the patient has no knowledge of any accident. The case history showed that a year after the original operation the acuity of the wounded eye was 6/4·5. Examination with the slit-lamp revealed the fact that there were two perforating scars on the cornea, one quite recent, the other very old. These scars have been already described. It was therefore perfectly clear that there had been two accidents, and that the eye contained a fragment of metal. This was shown in an X-ray plate and was localised by Sweet's apparatus in the vitreous. The eye was excised and the foreign body found in the region of the ora serrata. The legal point in this case, and it is a vital one, is that had the employé been working for two employers the first would have carried no liability. As a matter of fact in this case there was but one, and the observation had only an academical value.

The last case was a man of thirty who was standing near a fitter who was chipping metal, and was wounded in one eye. He was examined for compensation, and it was found that he had an eccentric corneal nebula with severe distortion of the cornea in the pupil area, and his acuity was low. There were several synechiæ and some lental opacities. The natural inference was to correlate the iritis with the corneal nebula. Examination with the slit-lamp showed that the corneal opacity was not a superficial nebula, but a keratitis profunda, doubtless following the insult. The synechiæ were seen to be of the type shown in Fig. 64, the intra-uterine type. When the pupil was contracted they folded up, when it was dilated they were seen as broad, flat bands. Each was inserted into the filmy cocoon-like material that we have already associated with the intra-uterine type of iritis. There were the usual groups of congenital " stars " due to the fact that the inflammatory process had inhibited the natural retrogression of the pupillary membrane. In a short time the cornea regained its normal contour, and full acuity was attained with a suitable cylinder. A conference was arranged between the two medical men who examined the case, and it was decided that there was no loss of wage-earning capacity.

These three cases exemplify the necessity of using the slit-lamp in all compensation cases. Even now some insurance companies are fully aware of the necessity of the slit-lamp, and it is only a matter of time for a slit-lamp examination to be demanded. The ophthalmic surgeon who does not employ the instrument stands sooner or later to lose prestige in court.

CHAPTER XV

THE RETINA, INTRA-OCULAR TUMOURS, AND GLAUCOMA

THE range of the corneal microscope is limited to a spot about one-third of the distance from the back of the lens to the retina. There are several reasons why the retina is invisible with the ordinary apparatus. One is that the optical conditions necessary for the formation of an image in the microscope are not satisfied; another, that it is not possible to approximate the axis of the lamp sufficiently near to that of the microscope to permit them to meet on the retina. To obtain a view of the deeper parts of the vitreous and of the retina the corneal curvature must be abolished by using a contact glass, and we must so modify the apparatus that it is possible to bring the illuminating ray as nearly as possible parallel to the central axis of the microscope.

The contact glass is curved on one side to fit the cornea, and the opposite side is flat. It can be inserted under the lids without the use of cocaine with the help of a little normal saline.

In order to obtain a very acute angle between the lamp and microscope Koeppe attaches a mirror to the illuminating lens and uses a microscope with one objective only. The arm of the slit-lamp is placed at right angles to the axis of the microscope, and the mirror is placed close to the objective. The microscope was devised by Siedentopf. It gives partial stereoscopic vision, and the image is inverted. An attempt has been made to erect the image, but it has not succeeded.

Kleefeld has invented a better method. He uses the ordinary Czapski microscope and hangs the slit-lamp from a kind of gallows. The illuminating lens is fitted with a horizontal mirror which is placed close to the objectives and above them. The apparatus was demonstrated to us at Brussels by Dr. Kleefeld. A young girl whose pupils were dilated for refraction was asked to lie upon a table, and with the aid of a little normal saline the contact glass was introduced. A few air bubbles collected under the glass and were expelled with a little more saline. The girl then sat at the slit-

lamp and a very beautiful view of the retina was obtained. The patient stated that she felt no discomfort from the contact glass.[1] The gallows attachment can be obtained in Brussels for a few pounds.

An exhaustive account of the results obtained with the contact glass in the examination of the vitreous and retina will be found in the second volume of Koeppe's book on the *Microscopy of the Living Eye*.

The technique is exceedingly difficult, and to obtain really good results the micro-arc lamp is used. It is probable that the contact glass may be of real value to differentiate between malignant and inflammatory swellings in the vitreous chamber. We cannot regard contact-glass work as coming within the scope of ordinary clinical work, but it may in the future yield valuable information to those who have sufficient time to devote to research work. A special form of contact glass has been used by Koeppe to examine the angle of the anterior chamber.

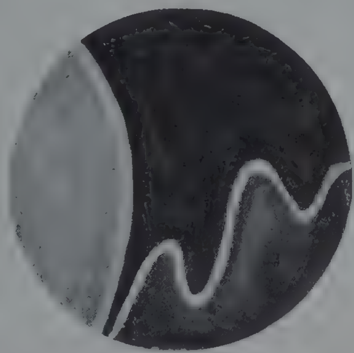


Fig. 149.—A detached retina, showing radial tension striæ in the vitreous.

Detached Retina.—If a detachment comes well forward it can often be seen with the ordinary slit-lamp and presents varied appearances. In one case it looked like black, hard, crumpled paper, but no vessels could be seen. With the ophthalmoscope the vessels were visible and the retina showed the usual signs of a detachment. In another patient with a total detachment, the central stalk with the retinal vessels were plainly seen. Another case showed a hole in the retina which could not be seen with the ophthalmoscope.

The example in Fig. 149 was an ordinary myopic detachment of normal aspect. No vessels could be made out with the slit-lamp. Radial fan-like lines were seen in the vitreous suggesting lines of tension or even strands. If these are the result of a contracting process it would appear that even in myopic detachment the retina is actually drawn off by contracting bands.

Detachment of the Choroid can be investigated with the slit-lamp, and in one case, after a trephining operation, we were able to decide that not only was the choroid separated but that the retina was detached from the choroid. In late cases of detached retina with secondary cataract the peripheral part of the retinal layer of the iris may be seen with the slit-lamp to be extensively atrophied, in

[1] A contact glass for the abolition of the distortion caused by a concise cornea is made by Zeiss and can be worn permanently without discomfort or harm to the cornea.

fact the periphery of the iris may be almost transparent. The angle of the anterior chamber in these cases is abnormally widely open.

Intra-ocular Tumours

There is often extreme difficulty in making a differential diagnosis between an intra-ocular malignant tumour and an inflammatory swelling: is it glioma or pseudo-glioma? The slit-lamp is of considerable value in this class of case. The presence of definite signs of inflammation is strong evidence in favour of pseudo-glioma; the failure of such signs supports the view that the swelling is malignant. The total absence of cells from the retro-lental space and the aqueous makes it very improbable that the eye is suffering from any form of exudative choroiditis—in other words, from a pseudo-glioma. On the other hand, the presence of particles in the aqueous cannot be taken as conclusive evidence that there is not a malignant growth in the eye. It has been shown that comparatively large tumour masses can pass the peri-lental space and appear in the aqueous, and there is always the possibility that blood cells may be present. The following two cases illustrate the value of the slit-lamp examination.

Fig. 150.—A pseudo-glioma seen with the ophthalmoscope.

At a meeting of the Midland Ophthalmological Society in 1926, Mr. St. Clair Roberts brought a case for diagnosis. A detached retina was present over a localised swelling in the eye of a child. The patient had been under observation for some months and no change had taken place. The child was very young and the slit-lamp examination difficult, but it definitely showed that there was no sign of any inflammation. This discovery strongly favoured the view that the swelling was not inflammatory, and the eye was excised. It was found to contain a melanotic sarcoma.

Figs. 150, 151 and 152 were taken from a case of the opposite kind. The child was three years of age and the slit-lamp examination presented no difficulties. The fundus, as seen in Fig. 150, showed a dead-white billowy mass in the vitreous chamber, and on one side the retina was detached. Holes in the white mass allowed the

red fundus reflex to be seen. The slit-lamp demonstrated cells in the vitreous, the retro-lental space, and aqueous. The tumour was seen with the narrow beam and localised to be almost touching the posterior capsule. This is illustrated in Fig. 151. There was a fine posterior synechia. The case was examined by Dr. Franceschetti, who happened to be in England, and he agreed that the swelling was almost certainly inflammatory. As there seemed to be a very slight doubt the eye was excised, and found to contain a retinal cyst and a pseudo-glioma (Fig. 152). The present position would appear to be that in a doubtful case the eye should be removed if no sign of inflammation can be found with the slit-lamp, and that the mere presence of particles in the anterior chamber and retro-lental space cannot be taken as positive evidence of non-malignancy. Any method which can afford the slightest help in these doubtful cases, cases in which a mistake may lead to a catastrophe, cannot be disregarded.

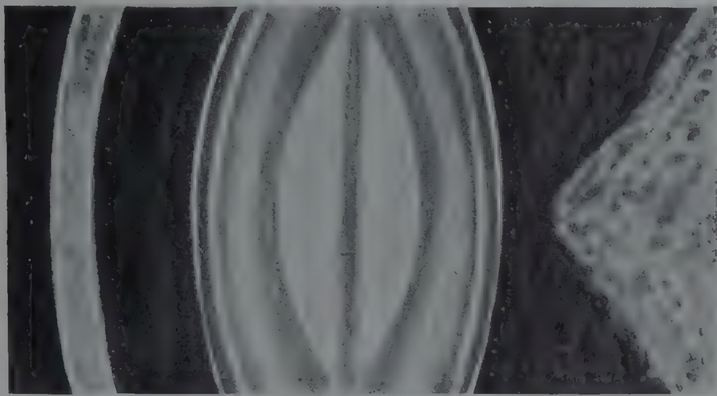


FIG. 151.—Optical section of the eye. The tumour-like mass is seen on the right coming close up to the lens. The vitreous and the aqueous contained cells which are shown in the drawing.

FIG. 152.—The excised eye containing a retinal cyst with total detachment.

GLAUCOMA

The slit-lamp may render useful service in the diagnosis and investigation of glaucoma. Koeppe describes an infiltration of the iris with pigment which he considers to be pathognomonic of glaucoma. We have noted this pigmentation in several cases of glaucoma, and in one case it was present in the glaucomatous eye and absent from the fellow eye, which showed no signs of the disease. On the other hand, Vogt and others have pointed out that

an exactly similar deposit is found in elderly persons who have not glaucoma, and every observer will be able to confirm this observation. We may conclude that Koeppe's infiltration with pigment is a sign of iris degeneration but not especially of glaucoma. It is well known

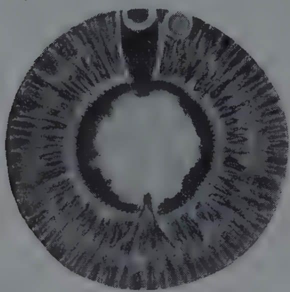


Fig. 153.—A corneal opacity after trephining.

Fig. 154.—The same in optical section through the centre of the opacity.

Fig. 155.—The opacity at its periphery.

that the iris often shows advanced signs of atrophy in long-standing glaucoma.

There is often great difficulty in deciding whether a case of glaucoma is primary, or secondary to a low-grade irido-cyclitis. It has been suggested that all glaucomas are secondary, but clinically we can and must separate the two varieties, for the treatment of the two classes is diametrically opposite. Examination with the slit-lamp will often show signs of inflammation of the cyclitic type which are difficult to detect with the loupe. We may find fine K.P., increased aqueous relucence, or even cells in the aqueous. These signs speak very forcibly for the secondary origin, and in the non-congestive types exclude a primary glaucoma.

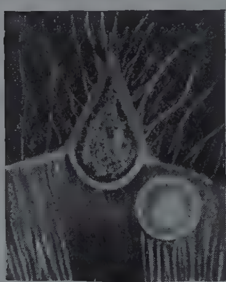


Fig. 156.—The trephine opening and the lost disc.

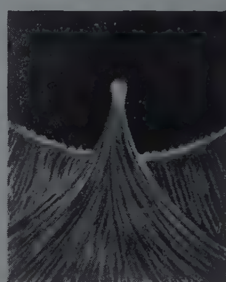


Fig. 157.—The iris adhesion to the cornea.

The case illustrated in Figs. 153 to 157 is of such an unusual type and caused so much anxiety that I have no hesitation in describing it. The patient was a woman of thirty who came to the Coventry Hospital for glasses. Her retina was so clearly visible with a Curry and Paxton electric ophthalmoscope that we made a prolonged examination to try to see the retinal circulation. We failed to discover any visible circulation, but noted a distinct arterial pulsation.

The Schiötz tonometer showed that the intra-ocular tension was 25. The patient was kept under careful observation, and eventually the field began to contract, pain was complained of, and the tension steadily rose in spite of the use of meiotics. The eye was trephined on April 9th, 1924. The conjunctiva was excessively thin and the sclera soft. The trephined disc fell into the eye and was not recovered. On the second day the conjunctiva gave way over the aperture, leaving a triangular defect which is seen in Fig. 156. The slit-lamp showed that the hole was covered by a delicate pellicle, but that the main thickness of the conjunctiva formed the sides of the triangle. The tension of the eye was very low and the anterior chamber had not re-formed. A fortnight after the operation, during which time the eye had been free from injection, a dense opacity formed in the centre of the cornea, as seen in Fig. 153. At the same time a small fold of iris became attached to the back of the cornea, shown in Figs. 153, 157. Examination with the slit-lamp revealed an apparently desperate condition. The cornea seemed to be greatly thickened and to be compactly fused with the lens. The lens capsule was drawn up tent-like at the sides to join the cornea, which in this situation was ivory-white and densely opaque. There was no change in texture between the lens and the cornea at the point of junction. Fig. 154 gives the appearance at the centre of the cornea. Fig. 155 a more lateral view. Three days later the anterior chamber had re-formed, and the lens and cornea had resumed their normal appearance ! In another week the small iris adhesion broke away from the cornea, leaving a spot of pigment. The eye did perfectly well, and to-day, two years later, has fair vision and normal tension. The case is difficult to explain. There was obviously an adhesion between the lens and cornea, probably due to some kind of opaque exudate which was largely responsible for the picture seen. The trephined disc is seen lying on the iris and to-day it has not altered its appearance.

We have seen that we can measure the depth of the anterior chamber with Ulbrich's drum with some approach to accuracy. This faculty is very useful in glaucoma, both in diagnosis and in estimating the success of treatment. See Fig. 44.

In acute glaucoma there is dense bedewing of the cornea in which we see clear lacunæ. This rather masks the aqueous and prevents an estimation of the aqueous flare. We are generally able to decide

that there is no iritis, except in protracted cases, and that there is no K.P.

In one case of very acute glaucoma, Mr. Nicholas Hughes, our house surgeon at the Birmingham Eye Hospital, discovered a central bulging of the cornea involving the whole thickness—that is to say, there was no thickening. This central convexity disappeared after operation. We have examined other cases, but have failed to find another example.

In another case we noted that the peri-limbal lymphatics were engorged and unduly obvious.

CHAPTER XVI

SLIT-LAMP TECHNIQUE APPLIED TO SIMPLE APPARATUS

THERE must always be occasions when an eye must be examined and no slit-lamp is available. The instrument is not portable, and not all patients can be brought to it. Many ophthalmologists have more than one consulting-room, and the cost of the apparatus forbids its duplication. Fortunately much of the technique that has been described in the early chapters can be carried out with the instruments that should be found in every consulting-room—an illuminating lamp, an electric ophthalmoscope, a condensing lens, and the ordinary loupe or binocular loupe. We have emphasised the fact that the most essential feature of the new method is not the magnification gained by the Czapski-Zeiss microscope, but the accurate command of the illumination, and the power of localisation conferred by the slit-lamp. Much of the work accomplished by the apparatus can be done with the ocular F 55, a magnification of 9 diameters, which is not much more than that of the loupe, and nearly all of it can be managed with A 0, which magnifies 14 times. It is therefore obvious that if we can supply a suitable focal beam we can accomplish much with the loupe, if this valuable instrument is used to its best advantage.

An effective beam can be gained by two methods: we can focus a bright linear source of light upon the eye with an ordinary condensing lens; or we can use the filament of the ophthalmoscope. Both methods are valuable. The latter plan was brought to our notice by Mr. Coulter of Newport. We have tried various sources of light. The pencil of light furnished by a point-o'-light lamp or by a motor head-light bulb has not proved so effective as the simpler plan of using a half-watt lamp which can be made to give a linear streak of bright light. A 60-watt bulb used at about four feet from the patient gives the best result. The lower candle-power bulbs are now not well made, the filament soon hangs in loops and the source of light is no longer linear. This simple lamp is cheap, always available,

can be run from the town supply, and properly used is very effective. Many electric ophthalmoscopes, especially the older pattern of the Hamblin,[1] will give a parallel beam if the bulb is drawn right back; if they do not they are out of adjustment and should be returned to the maker. This property has been taken advantage of in our *pocket slit-lamp* made by Messrs. Hamblin shown in Fig. 158. There is no hole in the mirror and the instrument gives a sharp beam of remarkable intensity. It costs forty shillings. Throughout this book many examples of the use of the loupe and half-watt lamp have been given and in some cases illustrated; these need not be repeated.

FIG. 158.—The pocket slit-lamp.

Half-watt Technique.—The lamp must be placed four or five feet from the patient, and at such a height that the plane of the circular filament lies on the line joining the patient's eye to the lamp. If it is higher or lower we shall not obtain a line of light, but a circle. The light is focused upon the cornea, and is seen as a bright line. The loupe is held between the thumb and forefinger by its cover, the middle finger raises the lid, and the ring and little finger rest upon the patient's forehead. The forehead of the observer rests upon his bent forefinger and an accurate focus is obtained by an alteration in the flexion of the ring finger. To see such phenomena as the actual circulation of the blood with the loupe, it is necessary to focus the loupe within a fraction of a millimetre. The condensing lens rests against the surgeon's forehead. By this method the patient and the observer are one, and any movement of the patient does not disturb either the focus of the lens or that of the beam. It is necessary to focus the beam just as accurately as the beam of the slit-lamp, and to learn simultaneously and instinctively to move the combined focus from one object to another. The pocket slit-lamp is used in a similar way.

Localisation.—The pocket slit-lamp is better for accurate localisation than the half-watt lamp. With it we obtain a definite corneal prism, and can determine three zones in the cornea: the epithelial surface, the endothelial surface, and an intermediate zone, the corneal stroma. We can therefore, in the cornea, say that an object is on the surface, in the substance, or on the back of the cornea. We can

[1] The latest pattern of the Hamblin Ophthalmoscope furnishes an excellent parallel beam and is most effective as a slit-lamp.

do no more, but this rough localisation is very valuable. It distinguishes between a deep and a superficial keratitis, and tells us that certain dots are not on the surface of the cornea, but are K.P. This determination is not always easy with an ordinary diffuse oblique illumination. With the half-watt lamp we utilise three surfaces of reflection : the corneal mirror, the mirror of the anterior capsule, and that of the posterior capsule of the lens. There is no definite corneal prism, the beam is not sharp enough to form one.

The pocket slit-lamp shows up the more marked zones of discontinuity in the lens, and affords a fairly accurate localisation of opacities. With both the half-watt lamp and the pocket slit-lamp a nuclear cataract is perfectly distinct, and a central opacity can be defined with ease. A lamellar cataract can be localised with the pocket slit-lamp. With both we are able to localise a posterior cortical or capsular cataract, but we cannot differentiate between a cortical and a capsular opacity. The depth of the anterior chamber can be gauged with reasonable accuracy, and occasionally moving particles can be seen in the aqueous. Increased flare if marked can be seen with the pocket slit-lamp and with the naked eye. We have recently seen the posterior of a normal lens with the loupe.

Methods of Illumination.—With the exception of retro-illumination from the posterior capsule for the examination of minutiæ in the cornea, all the varieties described for the slit-lamp are available. *Diffuse illumination* is gained by pushing the lens forward within the true focus. That given by the half-watt lamp is far more effective than the dim diffuse light furnished by the frosted bulb found in most hospitals, a form of light inefficient for oblique illumination and inappropriate for retinoscopy. All dark-rooms require two lights : a half-watt for focal illumination, and a bright frosted bulb in a Thorington's chimney for retinoscopy. The ordinary light is a bad compromise. *Focal illumination* is easy to obtain. The beam can be directed at will upon any part of the cornea, or the iris, and can be projected on to any portion of the lens, or into the vitreous. *Retro-illumination* is given from the iris and from the lens as a whole, probably mainly from the posterior capsule. *Specular illumination* is constantly used. With it under certain conditions we have seen that the endothelial shagreen is visible, but the magnification is insufficient to resolve it into cells. The anterior lens shagreen is a beautiful object, but the posterior is not seen except as a bright

area of light. The sutures of the cortex and of the adult nucleus are easily demonstrated. The Y's are only observed under pathological conditions.

Scleral Scatter is probably of more real value when obtained by simple methods than with the slit-lamp. It is very useful to detect diffuse opacities in the cornea.

Technique to find the Lens Shagreen.—The patient must direct his gaze in such wise that his line of sight bisects the angle between the visual axis of the observer and the illuminating axis, he must look half-way between the lamp and the loupe, and all three lines must lie in the same plane. The surgeon alters his position slightly till he gets the glare of the light from the lens and he then raises and lowers his head till the shagreen lustre is perceived. A slight alteration in adjustment brings out the sutures of the cortex, which, as we have stated already, are better seen in their entirety with the loupe than with the microscope.

The Vitreous.—Much can be gained by an examination of the vitreous with loupe and half-watt lamp. A detached retina which cannot be brought into view with the slit-lamp is often seen thus. Hæmorrhages and tumours are detected and the vitreous fibrils and pigment dots are visible. It is hardly possible to detect a pathological vitreous with the loupe unless very advanced, but asteroid hyalitis at once attracts the attention.

The visible circulation can be seen in a vascularised cornea and at the normal limbus, but the latter is difficult to detect and is a test of high proficiency with the loupe. It probably calls for exceptional eyesight and for dark-adaptation. The visible circulation in a pannus can sometimes be seen in daylight with the light of a half-watt lamp and loupe. Very occasionally focal illumination of the retina by the filament of the ophthalmoscope will demonstrate the circulation in the smaller vessels. This phenomenon has been observed not only by the author, but independently by Mr. Rudd, surgical registrar of the Birmingham Eye Hospital.

Technique to see the Visible Circulation.—In all cases, even in the retina, the vessel must be viewed by retro-illumination. In the case of the limbus the light is focused on to the sclera in such wise that it is reflected back through a conjunctival vessel to the eye of the observer. Corneal vessels are illuminated from the iris, and retinal vessels from a deeper layer of the retina.

The pocket slit-lamp is of very real value to one trained in slit-lamp technique, who not only realises exactly how to manipulate the light, but also knows what he is looking for. An object previously invisible with the loupe is often seen perfectly when it has been examined with the slit-lamp.

Other Uses of the Slit-lamp.—The slit-lamp is very effective in demonstrating the hemianopic pupil reaction. The smallest pin-hole diaphragm is required.

Another use of the slit-lamp is for the detection of miners' nystagmus. The conditions of illumination are those that are most likely to elicit oscillation of the globes and the smallest movement is seen with the microscope.

The difficulty of slit-lamp technique has been exaggerated, especially by some authors who have suggested that the use of the slit-lamp is the province of a few super-specialists. The slit-lamp is not more difficult to use than the ophthalmoscope; the intelligent use of either instrument is the result of careful instruction and considerable practice. It is certainly true that elderly men do not acquire facility with new instruments as easily as the young, but in the end they may gain full proficiency.

The slit-lamp does not replace but supplements the older methods of examination. It should not be used before the eye has been examined with the ophthalmoscope and by oblique illumination with a half-watt lamp and loupe.

INDEX